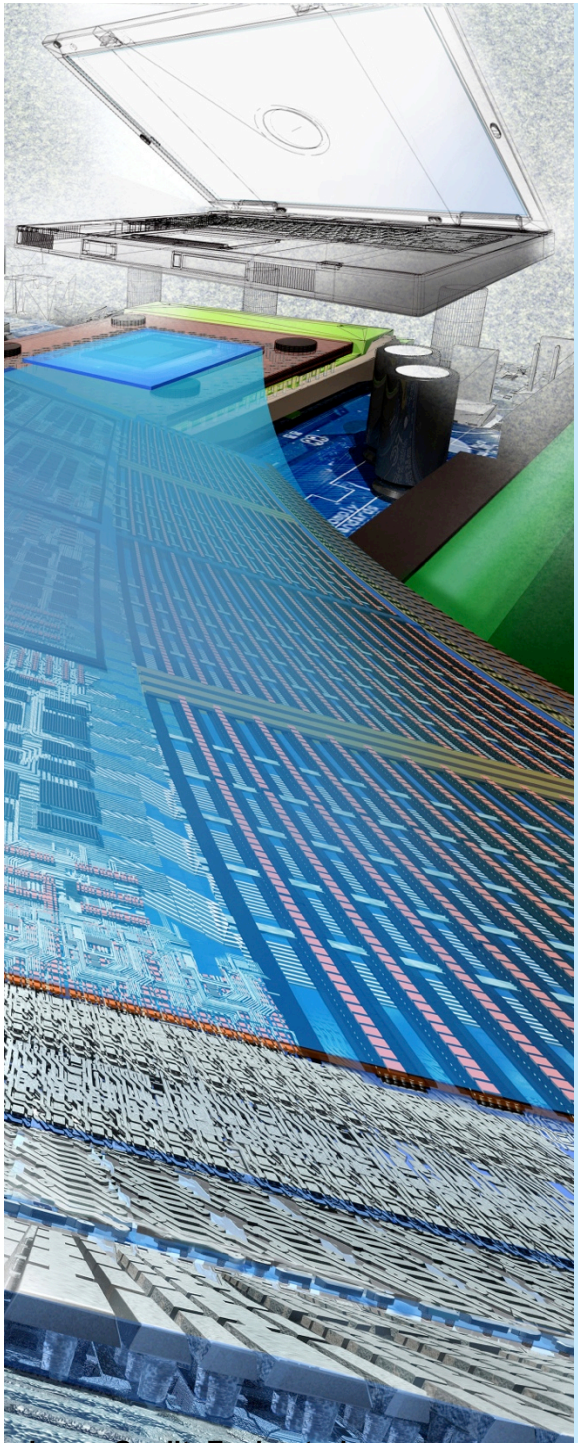


# Innovating for Society: Realizing the Transformative Impact of Computing and Communications

**Farnam Jahanian**
**CISE Directorate**
**National Science Foundation**

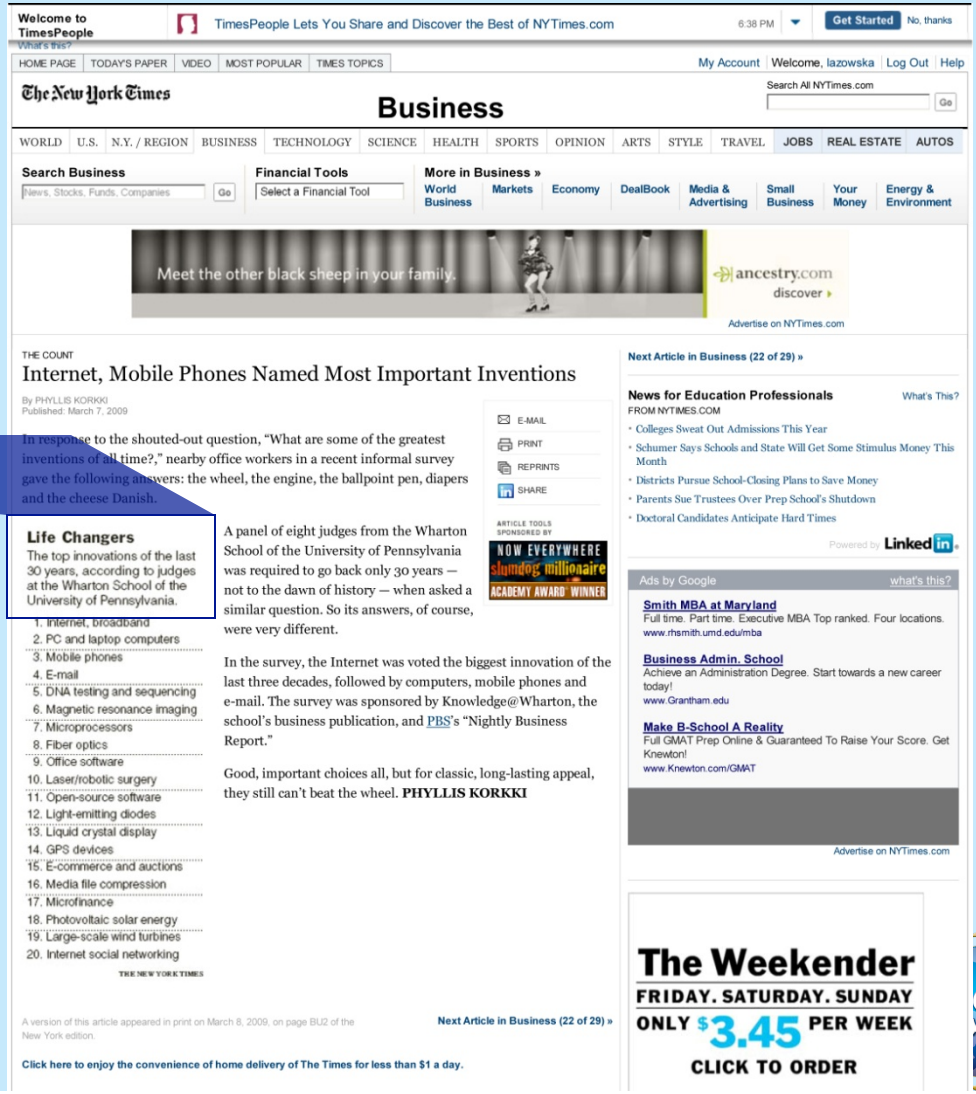
**December 2012**

# Pervasive Impact

- Our community is at the center of an ongoing societal transformation and will be for decades to come.
- Advances in computing, communications and information technology:
  - Underpin our **economic prosperity and national security**;
  - Serve as a key driver of U.S. **competitiveness** and sustainable **economic growth** in an increasingly global market;
  - **Accelerate the pace of discovery and innovation** in nearly all other fields of inquiry;
  - Are crucial to achieving our major **national and societal priorities**.

# The past thirty years …

**Life Changers**
The top innovations of the last 30 years, according to judges at the Wharton School of the University of Pennsylvania.



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THE COUNT
Internet, Mobile Phones Named Most Important Inventions
By PHYLLIS KORKKI
Published: March 7, 2009
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19. Large-scale wind turbines
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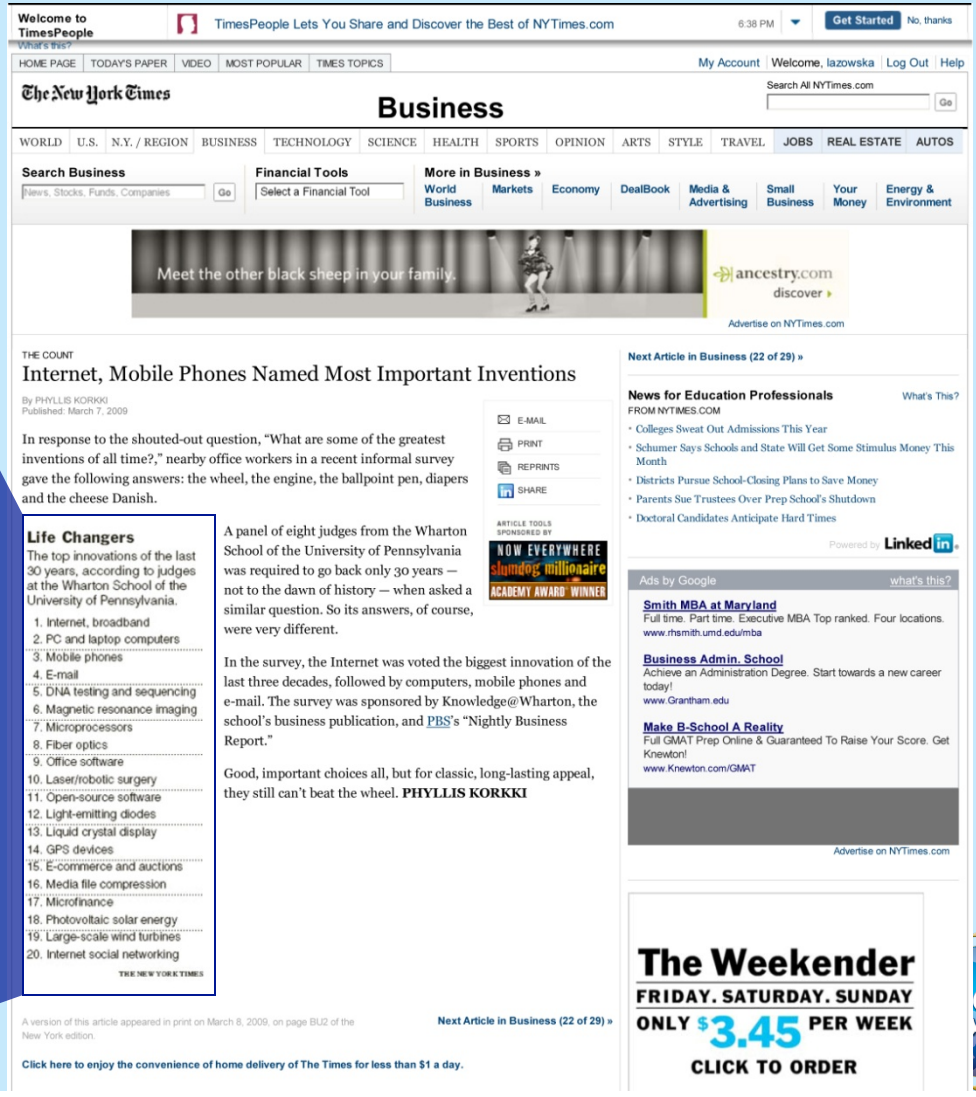
THE NEW YORK TIMES



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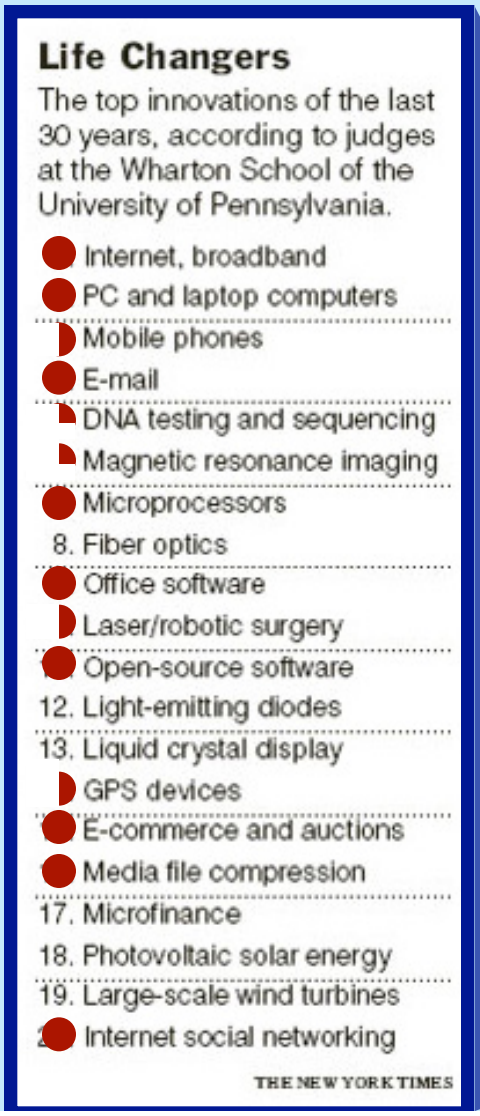

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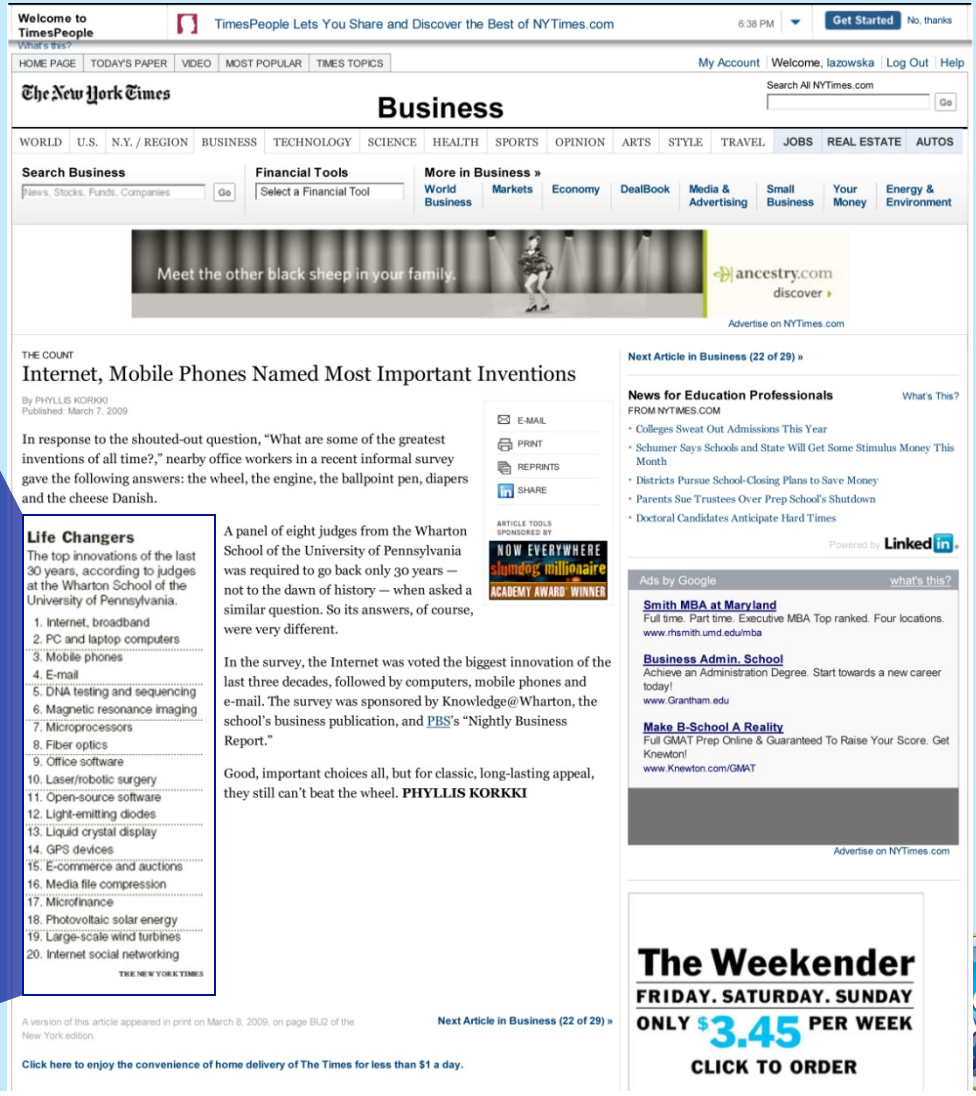

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FROM NYTIMES.COM

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- Schumer Says Schools and State Will Get Some Stimulus Money This Month
- Districts Pursue School-Closing Plans to Save Money
- Parents Sue Trustees Over Prep School's Shutdown
- Doctoral Candidates Anticipate Hard Times

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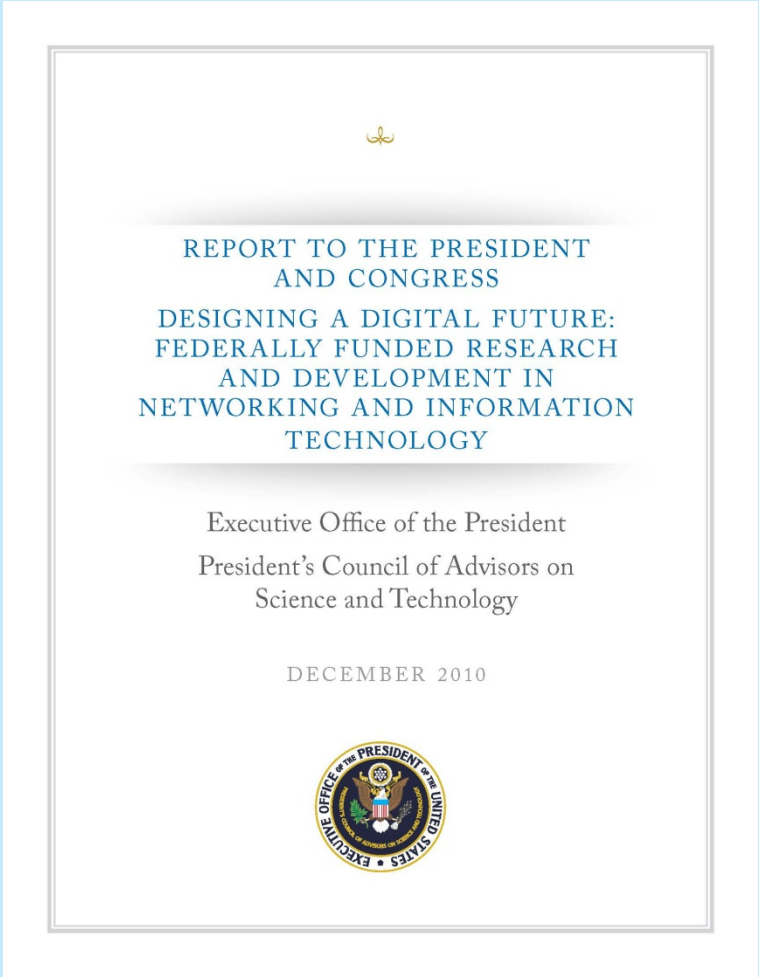
# A National Imperative




http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nitrd-report-2010.pdf

*"Recent technological and societal trends place the further advancement and application of networking and information technology squarely at the center of our Nation's ability to achieve essentially all of our priorities and to address essentially all of our challenges."*

Source: PCAST (2010). Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology. – A periodic congressionally-mandated review of the Federal Networking and Information Technology Research and Development (NITRD) Program.

# CISE and National Priorities

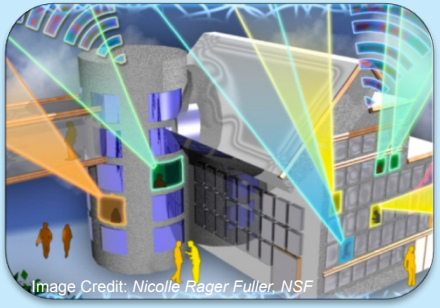


Image Credit: *Nicolle Rager Fuller, NSF*

**Broadband & Universal Connectivity**

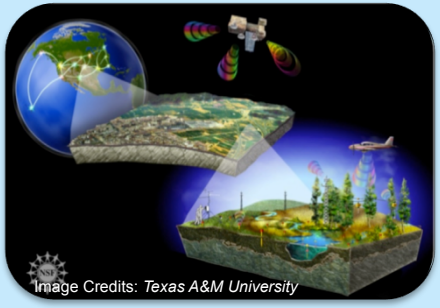


Image Credits: *Texas A&M University*

**Environment & Sustainability**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**Emergency Response & Disaster Resiliency**

**Health & Wellbeing**


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**Manufacturing, Robotics, & Smart Systems**


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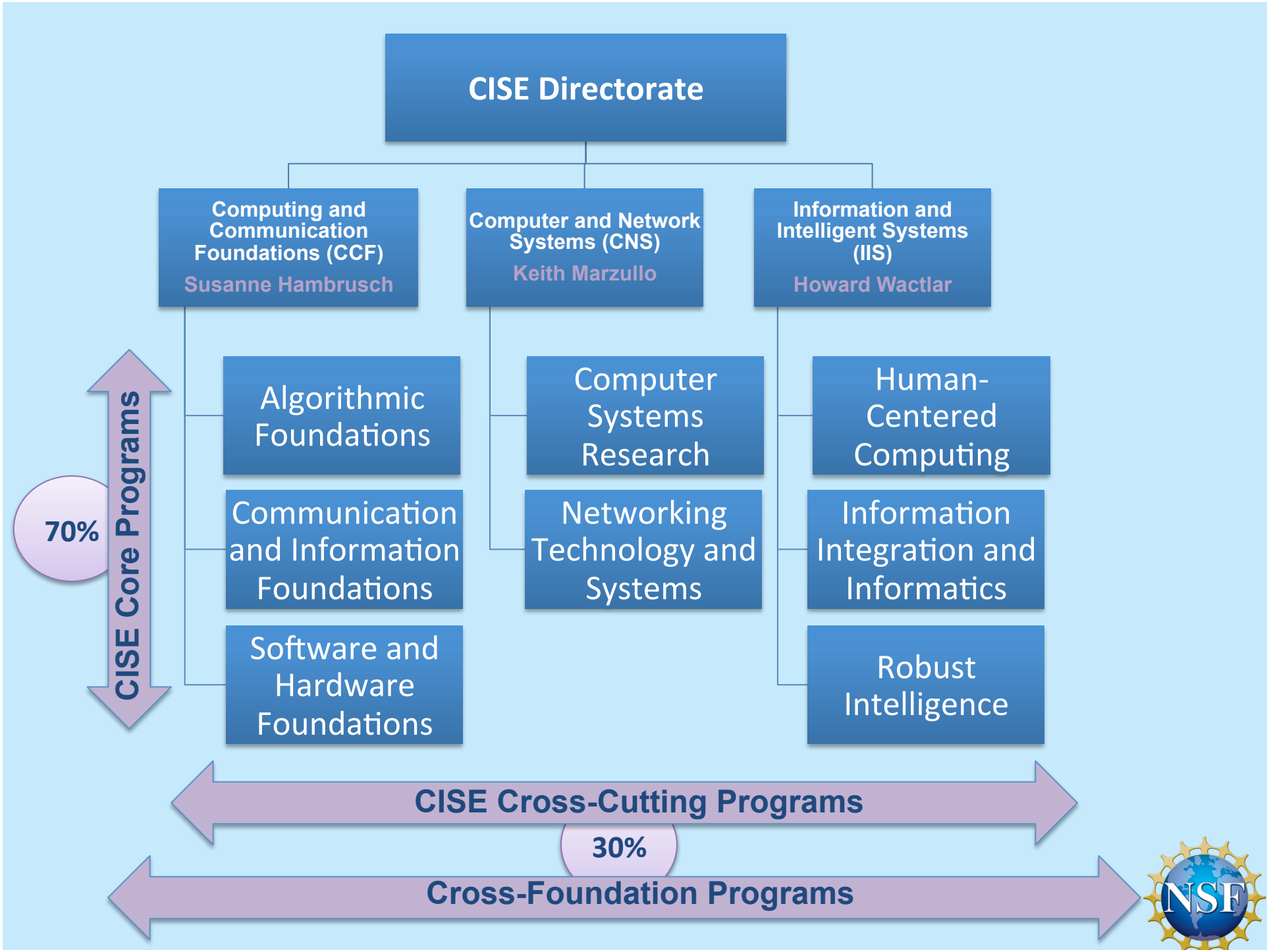
**Secure Cyberspace**


Image Credit: *Cisco, Inc.*

**Transportation & Energy**


Image Credit: *Georgia Computes! Georgia Tech*

**Education and Workforce Development**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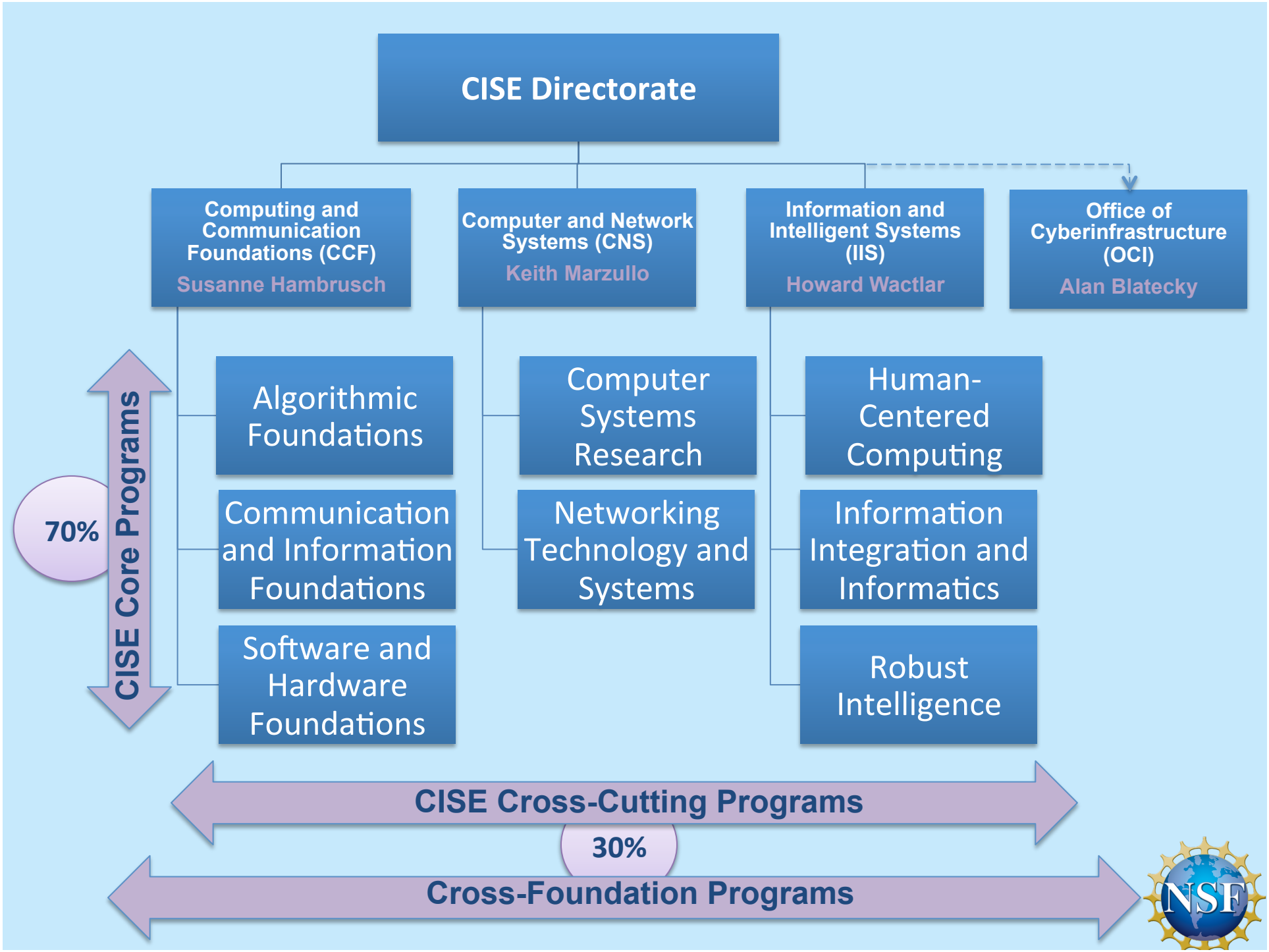
Computer and Network Systems (CNS)
Keith Marzullo
Information and Intelligent Systems (IIS)
Howard Wactlar
Algorithmic Foundations
Communication and Information Foundations
Software and Hardware Foundations
Computer Systems Research
Networking Technology and Systems
Human-Centered Computing
Information Integration and Informatics
Robust Intelligence
70%
CISE Core Programs
CISE Cross-Cutting Programs
30%
Cross-Foundation Programs
NSF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Software and Hardware Foundations
Computer Systems Research
Networking Technology and Systems
Human-Centered Computing
Information Integration and Informatics
Robust Intelligence
CISE Cross-Cutting Programs
30%
Cross-Foundation Programs
NSF

# Strong Commitment to the Core

*"NSF continues to **cast a wide net and let the best ideas surface**, rather than pursuing a prescriptive research agenda. It engages the [research] community in **developing new fundamental ideas**, which are then evaluated by the best researchers through the merit review process. This process, which supports the vast majority of unclassified [computing] research in the United States, has **led to innovative and transformative results**."*

-Testimony of Farnam Jahanian before the House Subcommittee on Technology and Innovation and the House Subcommittee on Research and Science Education , May 2011.


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computing
networks
data
analysis
security
wireless
learning
robotics
distributed
software
architecture
information
communication
algorithms
models
social
modeling
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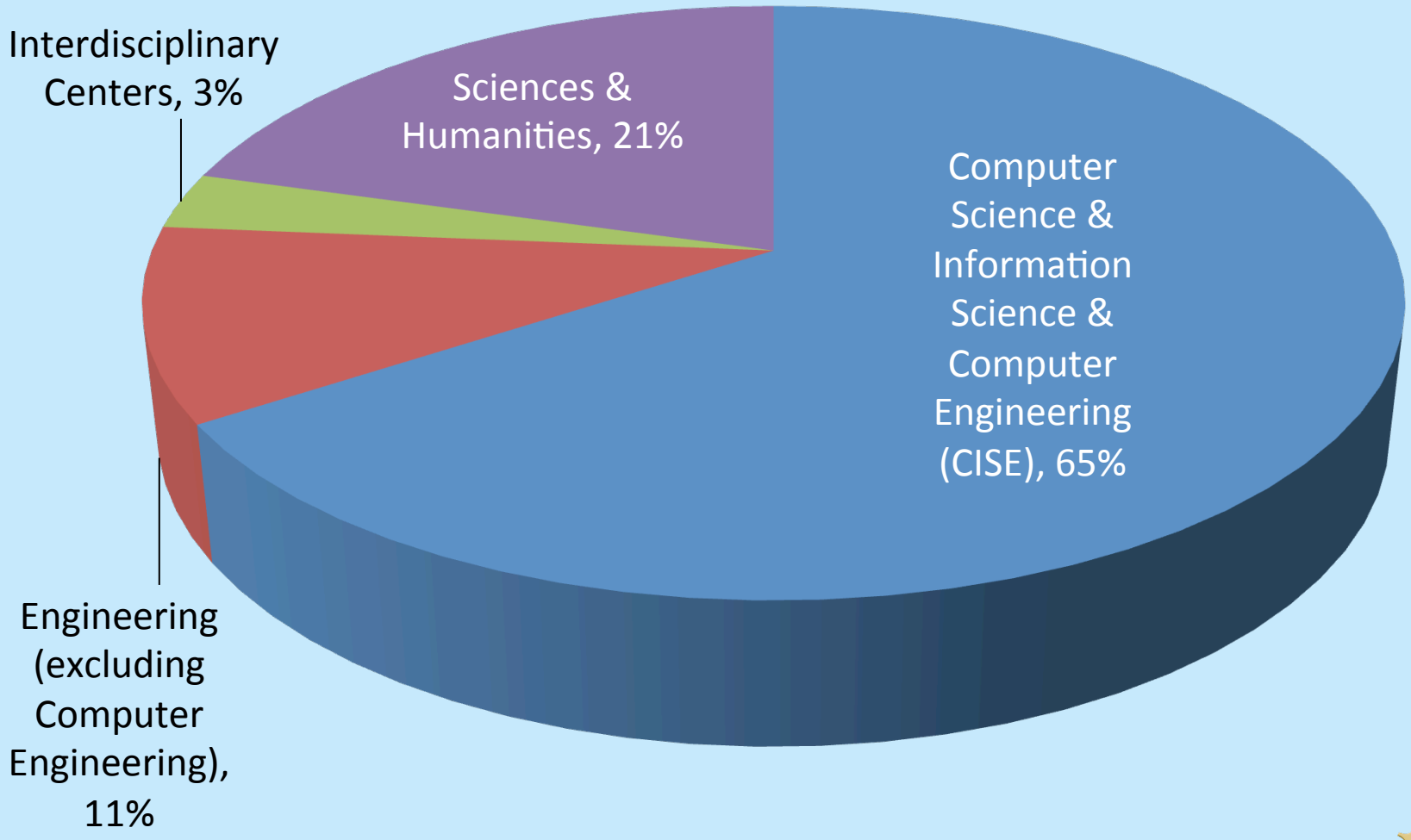
computation
framework
performance
scalable
infrastructure
networking
theory
computer
machine
sensing
language
media
knowledge
science
visualization
interaction
technology
parallel
system
storage
power
secure
privacy
model
visual
online
inference
societal
virtual
cognitive
circuits
energy
real-time
embedded
programming
computational
optimization
mobile
processing
sensor
health
control
signal
interactive

# Who is the CISE community?

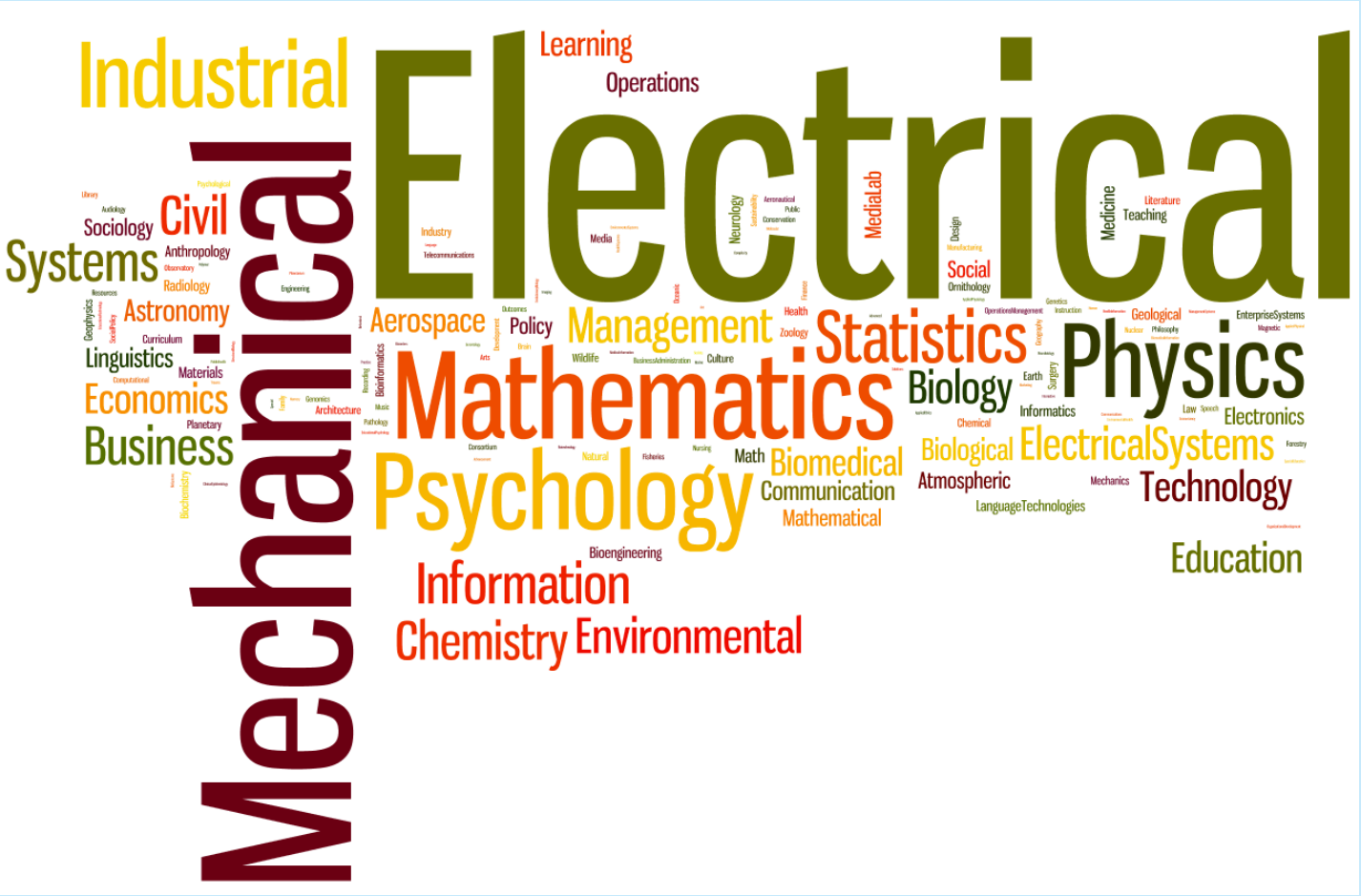
**PI and Co-PI Departments for FY 2011 Awards Funded by CISE**



# Who is the CISE community?

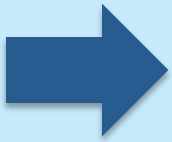
More than Computer and Information Scientists and Engineers!

Includes other disciplines and increasingly entrepreneurs and industry partners.



# Snapshot of FY 2012 Activities

| | CISE |
|---|---|
| Research Budget | $653M |
| Number of Proposals | 6,838 |
| Number of Awards | 1,508 |
| Success Rate | ~20% |
| Average Award Size | $171K |
| Number of Panels Held | 275 |
| Number of People Supported | 16,644 |



| | CISE |
|---|---|
| Senior Researchers | 7,553 |
| Other Professionals | 617 |
| Postdoctoral Associates | 366 |
| Graduate Students | 5,758 |
| Undergraduate Students | 2,350 |

# Budget from FY 2010 - 2013

| | FY 2010 Actual ($M) | FY 2011 Actual ($M) | FY 2012 Estimate ($M) | FY 2013 Request ($M) |
|---|---|---|---|---|
| **CISE Total** | **$618.71** | **$636.06** | **$653.59** | **$709.72** |
| NSF Research | $5,615.33 | $5,608.38 | $5,689.00 | $5,983.28 |

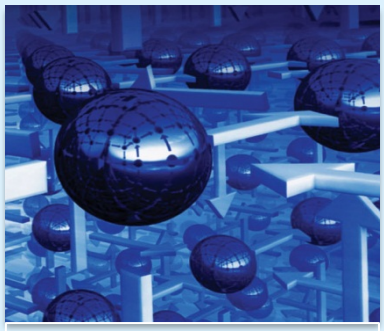
# Strategy

- Leverage the CISE community's intellectual leadership in addressing national priorities.
- Promote research agenda led by our community to cross-NSF or cross-agency efforts.
- Sustain long-term commitment to emerging areas of exploration.
- Advance the research frontiers through the right science at the right scale.
- Build on broad bi-partisan support for science and engineering research to cultivate support.

# Research Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision



Expanding the Limits of Computation

Secure Cyberspace

Universal Connectivity

Augmenting Human Capabilities

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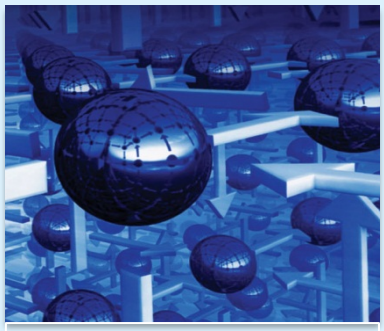

Expanding the Limits of Computation

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Augmenting Human Capabilities

# Seizing the Big Data Revolution

- **Data Tsunami: Explosive Growth in Size, Complexity, and Data Rates**
  - Enabled by experimental methods, observational studies, scientific instruments, simulations, email, videos, images, click streams, Internet transactions … and sensors everywhere!

- **The Age of Data: From Data to Knowledge to Action**
  - Widespread use of data to create actionable information leads to timely and more informed decisions and actions.

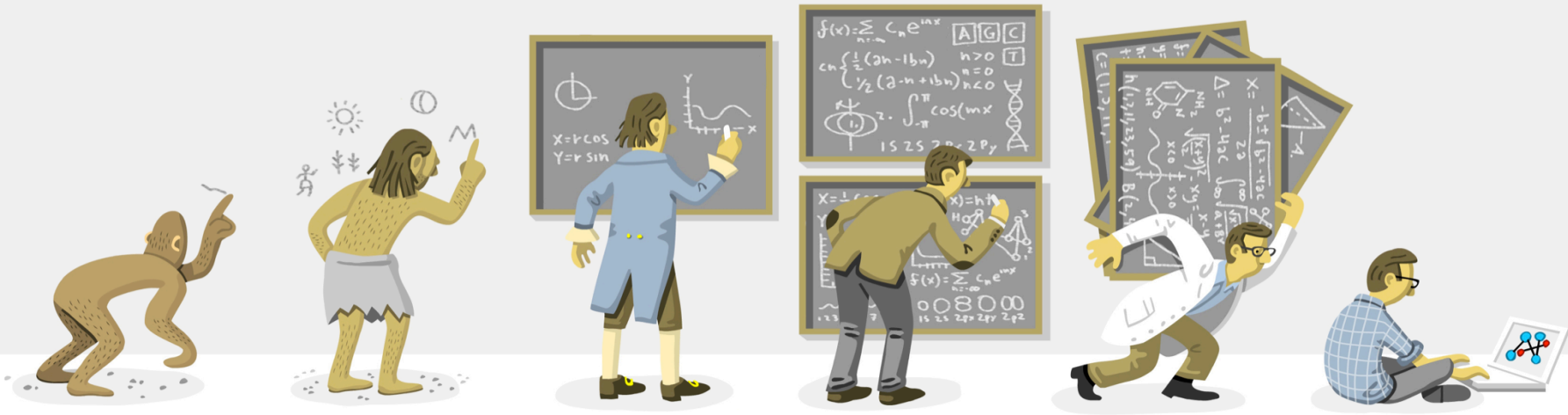
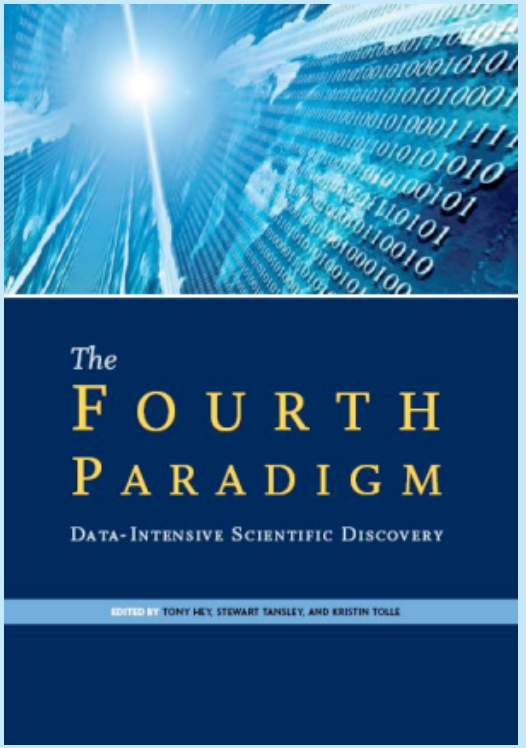


Image Credit: *Chi Birmingham*

# Paradigm Shift: from Hypothesis-driven to Data-driven Discovery


http://www.sciencemag.org/site/special/data/


http://www.economist.com/node/15579717

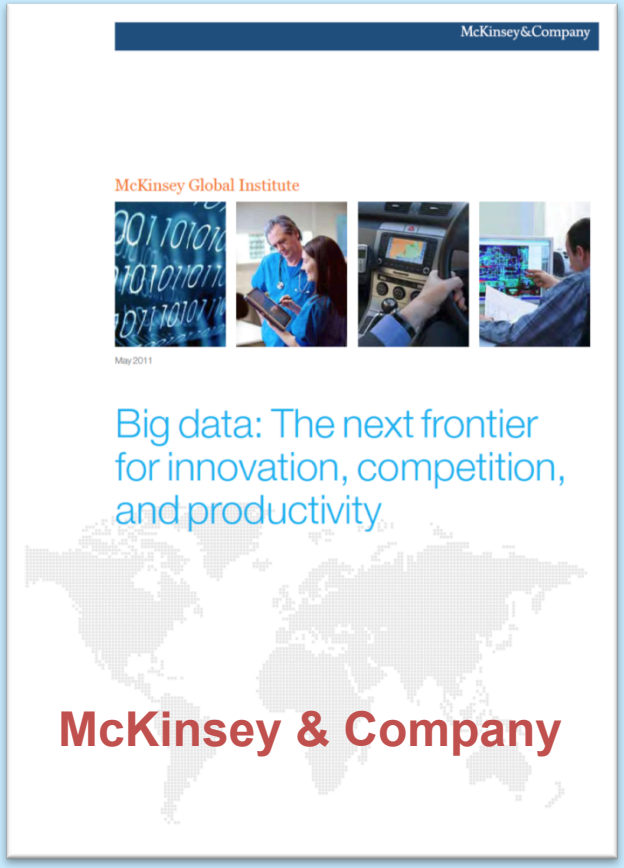



http://research.microsoft.com/en-us/collaboration/fourthparadigm/

**Data are motivating a profound transformation in the culture and conduct of scientific research.**

NSF

# Education, Learning, Workforce Development, Computational and Data-enabled Science

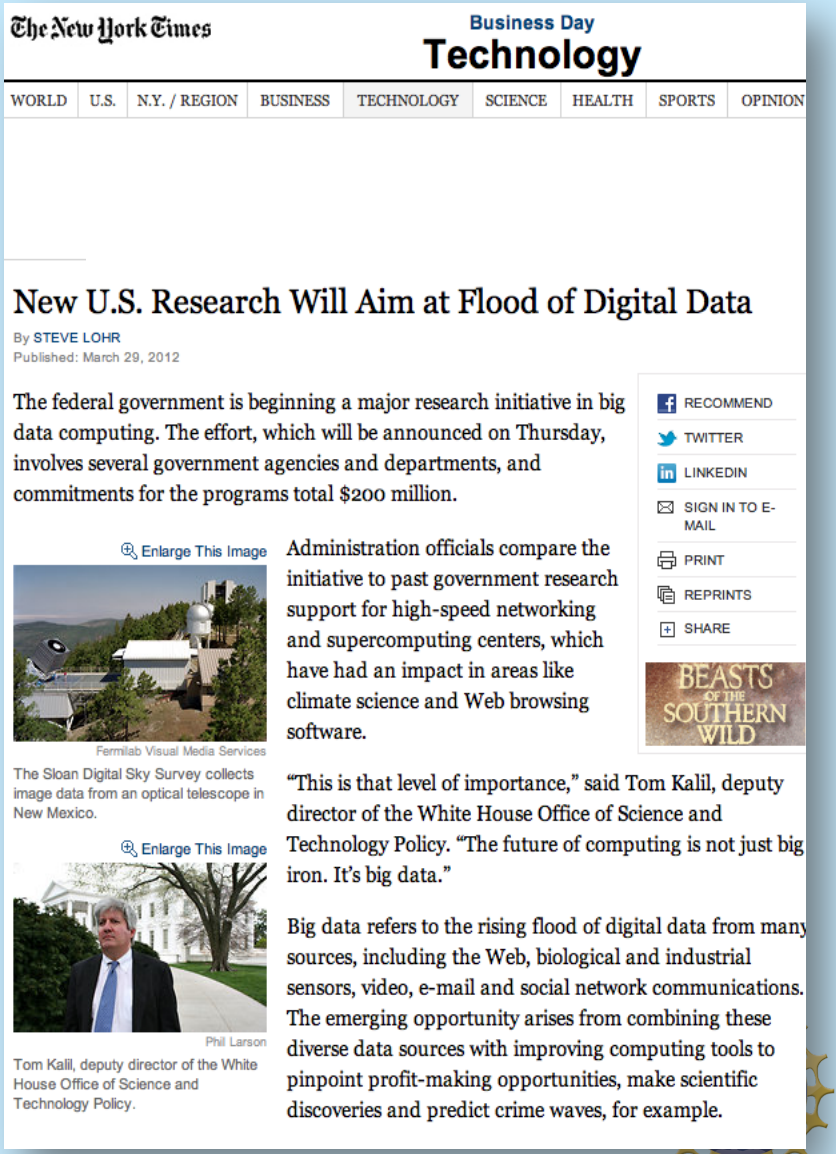



"By 2018 the United States alone faces a shortage of 140,000 to 190,000 people with analytical expertise and 1.5 million managers and analysts with the skills to understand and make decisions based on the analysis of big data."[1]

[1] McKinsey&Company (May 2011), "Big data: The next frontier for innovation, competition, and productivity." Available at: http://www.mckinsey.com/Insights/MGI/Research/Technology_and_Innovation/Big_data_The_next_frontier_for_innovation

# Federal Big Data R&D Initiative

- Federal Big Data R&D Initiative launched by White House OSTP on March 29, 2012
- Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIG DATA)
  - Joint solicitation between NIH and NSF
  - 3 research thrusts
    1. Collection, Storage, and Management
    2. Data Analytics
    3. Research in Data Sharing and Collaboration



The New York Times

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## New U.S. Research Will Aim at Flood of Digital Data

By STEVE LOHR
Published: March 29, 2012

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The Sloan Digital Sky Survey collects image data from an optical telescope in New Mexico.

Administration officials compare the initiative to past government research support for high-speed networking and supercomputing centers, which have had an impact in areas like climate science and Web browsing software.

"This is that level of importance," said Tom Kalil, deputy director of the White House Office of Science and Technology Policy. "The future of computing is not just big iron. It's big data."

Enlarge This Image

Phil Larson

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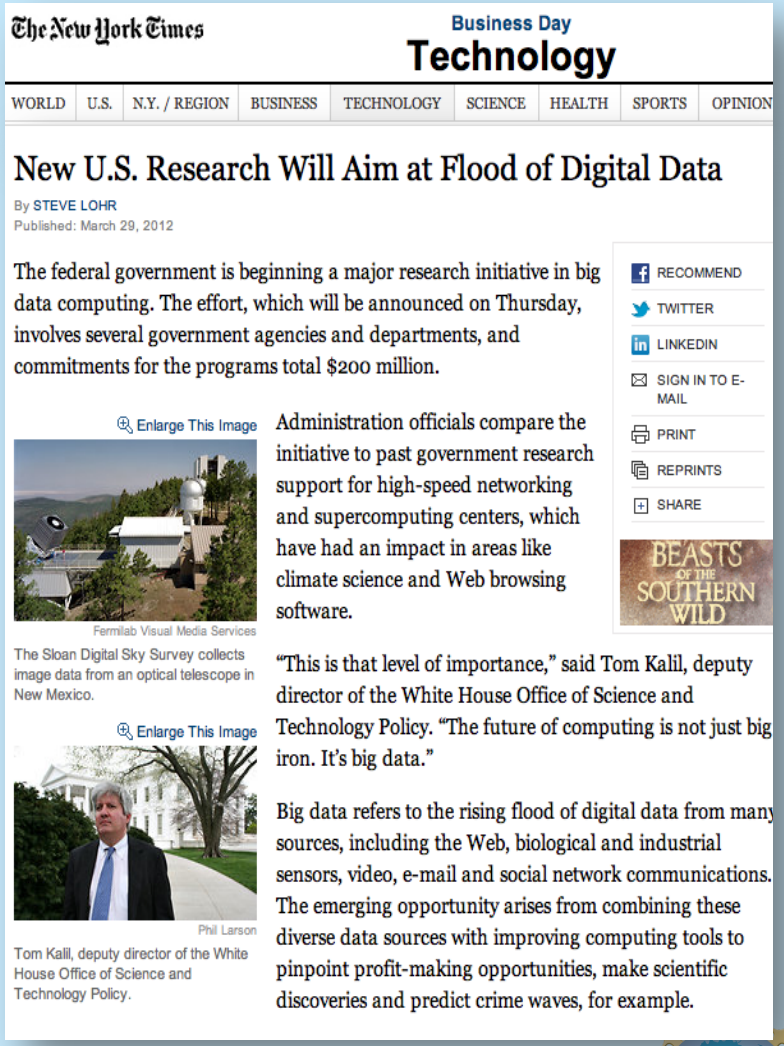
Big data refers to the rising flood of digital data from many sources, including the Web, biological and industrial sensors, video, e-mail and social network communications. The emerging opportunity arises from combining these diverse data sources with improving computing tools to pinpoint profit-making opportunities, make scientific discoveries and predict crime waves, for example.

More information available at:
http://nsf.gov/news/news_summ.jsp?org=CISE&cntn_id=123607&preview=false

# Federal Big Data R&D Initiative
## (Launched on March 29,2012)

- **Cross-agency "Big Data" Senior Steering Group –** chartered in spring 2011 by the White House OSTP:
  - Co-chaired by NSF and NIH
  - Significant research community input
- **Major Announcements**: NSF, NIH, USGS, DoD, DARPA, DOE
- **NEW PROGRAM**: Core Techniques and Technologies for Advancing Big Data Science & Engineering (BIG DATA)
  - All NSF Directorates and 8 NIH Institutes
  - Research thrusts: Collection, Storage, and Management; Data Analytics; Research in Data Sharing and Collaboration



The New York Times — Business Day — Technology

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More information available at:
http://nsf.gov/news/news_summ.jsp?org=CISE&cntn_id=123607&preview=false

# Extracting Knowledge from Data

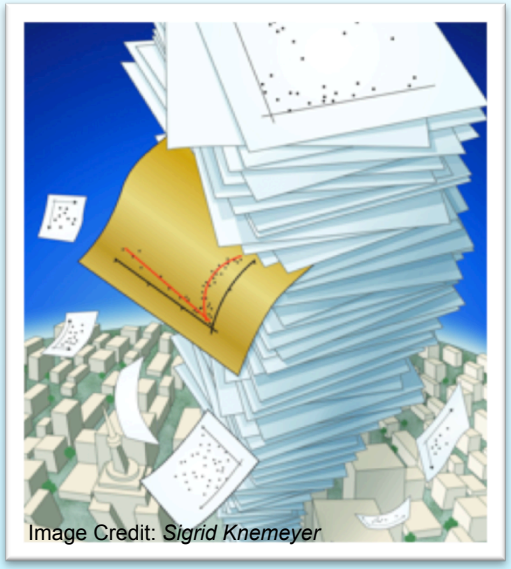
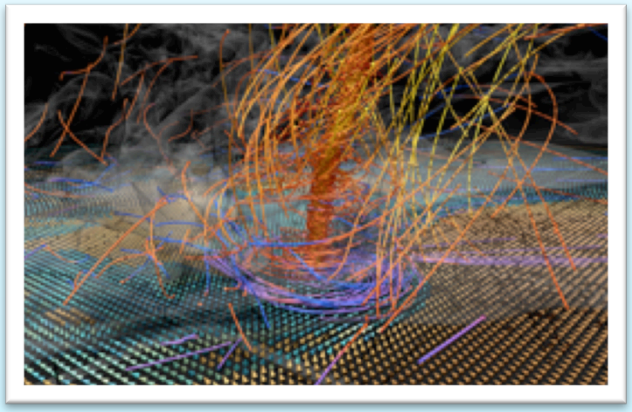


Image Credit: *Sigrid Knemeyer*

**New Tool for Extracting Knowledge from Large Data Sets:** A new statistical tool, part of a suite called MINE, can tease out multiple patterns hidden in health information from around the globe, statistics amassed from major league baseball, data on bacterial biodiversity, and much more. (Michael Mitzenmacher, Harvard with researchers from the Broad Institute)



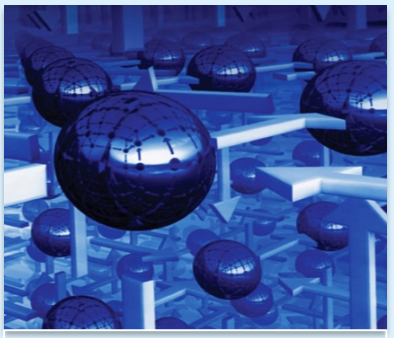
**Forecasting Tornadoes:** Parallel computing, data mining, and meteorology are being used to determine tornado formation and more reliable tornado forecasting. (Amy McGovern and Kevin Droegemeier, University of Oklahoma)

Image Credit: Bob Wilhelmson, NCSA and the University of Illinois at Urbana-Champaign; Lou Wicker, National Oceanic and Atmospheric Administration's National Severe Storms Laboratory; Matt Gilmore and Lee Cronce, University of Illinois atmospheric science department. Visualization by Donna Cox, Robert Patterson, Stuart Levy, Matt Hall and Alex Betts, NCSA

# Emerging Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision



Expanding the Limits of Computation

Secure Cyberspace

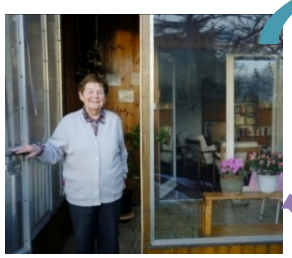
Universal Connectivity

Augmenting Human Capabilities

# Smart Systems: Sensing, Reasoning, and Decision

## Environment Sensing



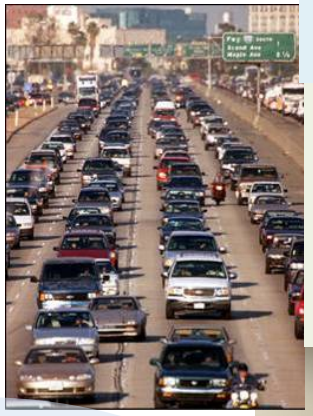

Percepts (sensors)

Agent (Reasoning)

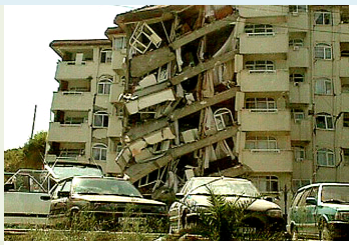
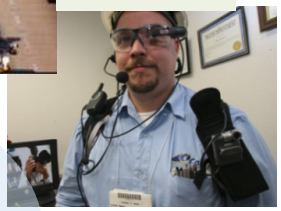
Actions (controllers)

Pervasive Computing

## Emergency Response



Situation Awareness : Humans as sensors feed multi-modal data streams


Social

## People-Centric Sensing

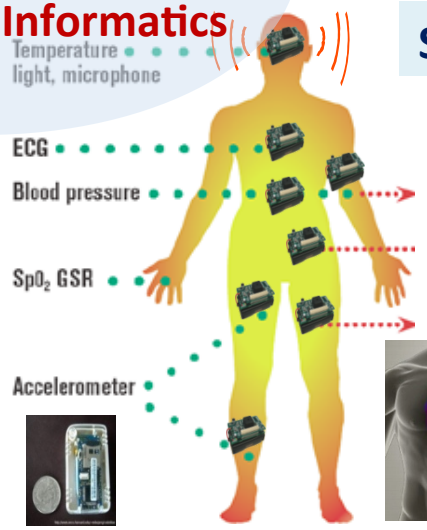



Public Sensing

Social Sensing

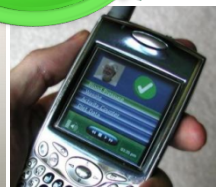
Personal Sensing

## Informatics




## Smart Health Care





Source: Sajal Das, Keith Marzullo

Credit: Image courtesy of University of Florida

# Research to Enable Smart Systems

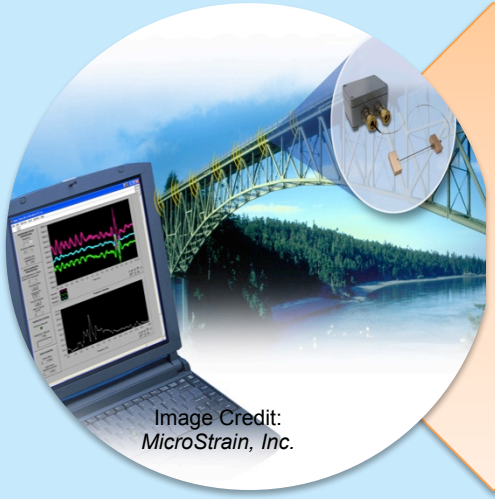


Image Credit: *MicroStrain, Inc.*

## Cyber-Physical Systems (CPS)

- ***Deeply integrate computation, communication, and control into physical systems***
- Aspects of CPS include pervasive computation, sensing and control; networking at multi- and extreme scales; dynamically reorganizing/reconfiguring systems; and high degrees of automation
- Dependable operation with high assurance of reliability, safety, security, and usability

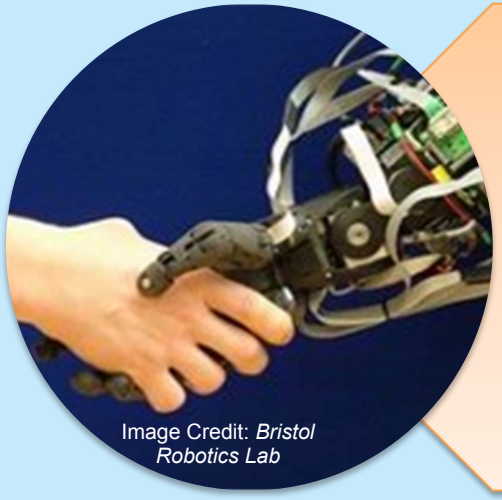
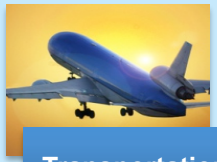


Image Credit: *Bristol Robotics Lab*

## National Robotics Initiative (NRI)

- ***Develop the next generation of collaborative robots, or co-robots, that work beside and cooperatively with people***
- A nationally concerted cross-agency effort among NSF, NASA, USDA, and NIH
- Initiative includes aim to understand the long-term social, behavioral, and economic implications
- Potential to enhance personal safety, health, and productivity

Application sectors



Transportation

Energy and Industrial Automation

Health and Medical Care

Critical Infrastructure

NSF

# The National Robotics Initiative (NRI)

A **nationally coordinated** program across multiple government agencies to develop the **next generation of robotics**, to advance the **capability and usability** of such systems and artifacts, and to encourage existing and new communities to focus on **innovative application areas**.


NSF

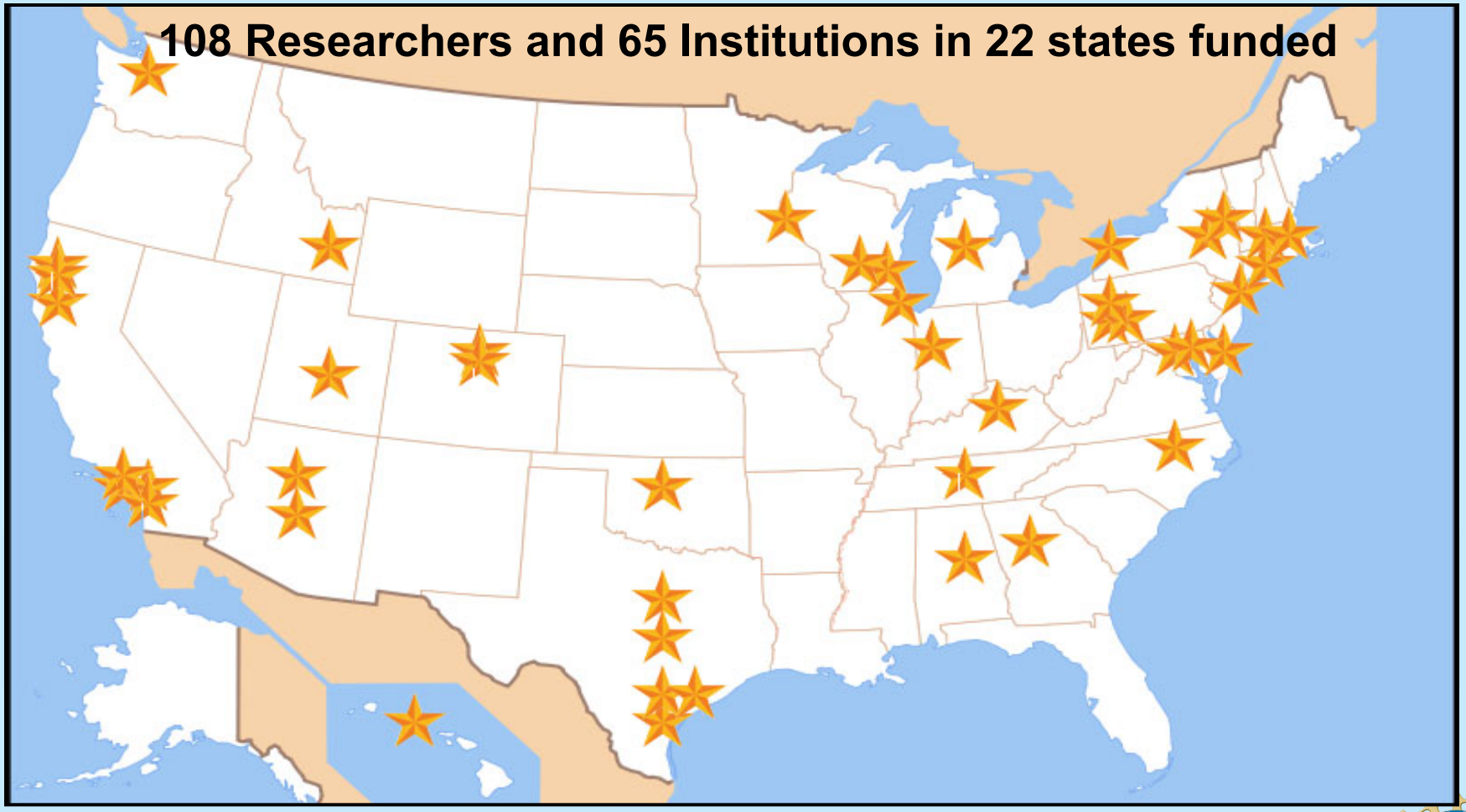
NASA

NATIONAL INSTITUTES OF HEALTH

USDA

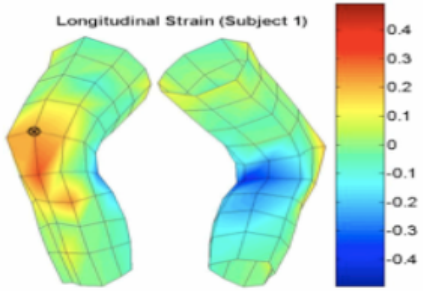
United States Department of Agriculture
National Institute of Food and Agriculture

# *"If you build it, they will come"*



# Broad Applications for Smart Systems

**Assistive Medical Technologies:** Programmable second skin senses and re-educates injured nervous systems. (Eugene Goldfield, Harvard Medical School)



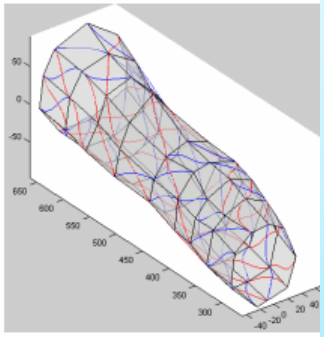



Image Credit: Wyss Institute, Harvard University

**Towel-folding Robots**: Development of novel computer vision and algorithms enable robots to manipulate flexible objects that change shape. (Pieter Abbeel, UC Berkeley)

Credit: Provided by NSF

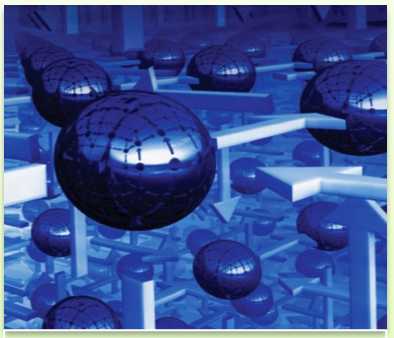
**Autonomous Vehicles**: Development of precision and real-time sensors, smart algorithms, and verification tools enabling self-driving cars. (Ragunathan "Raj" Rajkumar, CMU, et al.)


http://www.nsf.gov/news/special_reports/science_nation/carswithoutdrivers.jsp

# Emerging Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision



Expanding the Limits of Computation

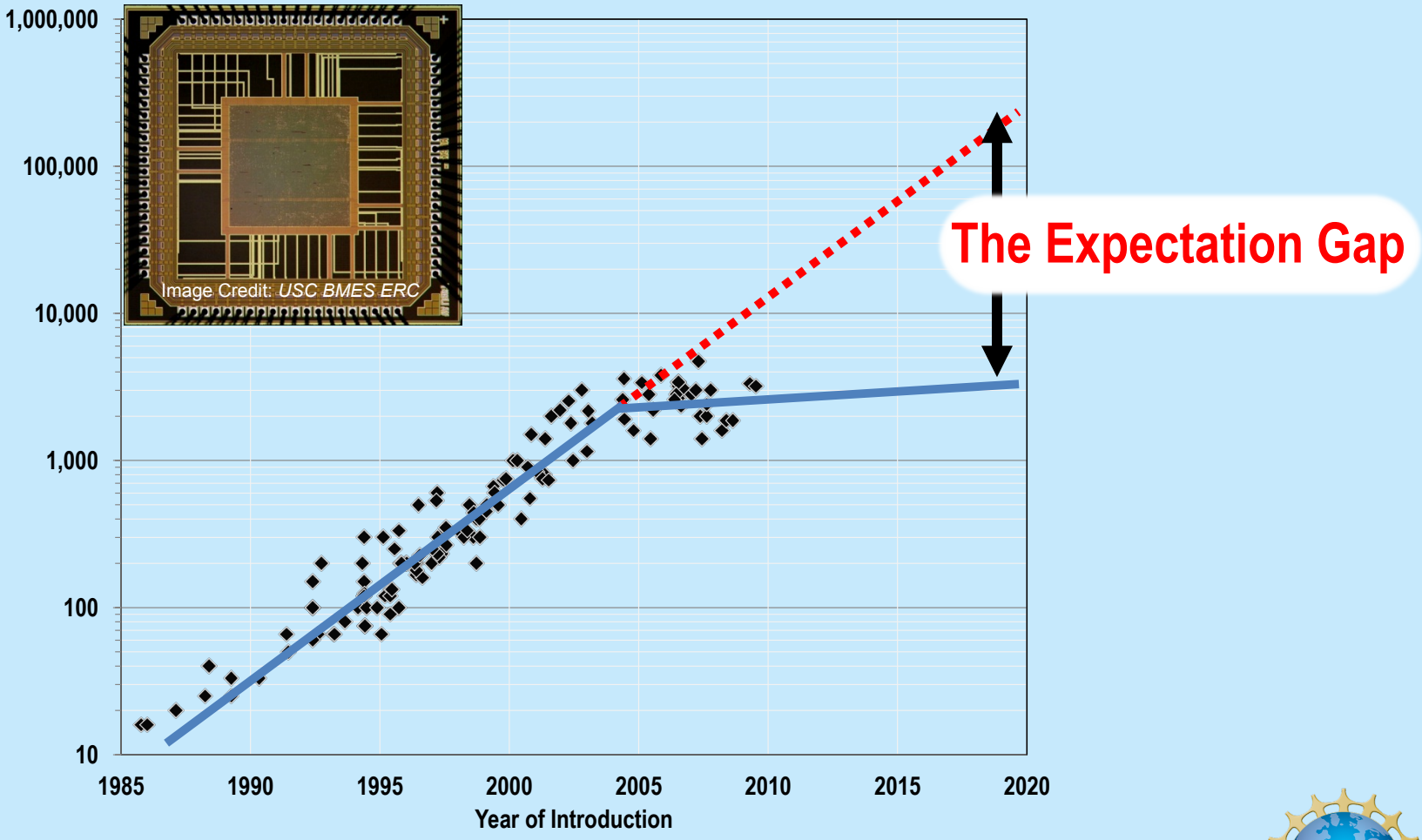
Secure Cyberspace

Universal Connectivity

Augmenting Human Capabilities

# Processor Performance Plateaued Around 2004

**Microprocessor Performance "Expectation Gap" over Time** (1985-2020 projected)




**Credit: Graph reprinted with permission from *The Future of Computing Performance: Game Over or Next Level?* National Academy of Sciences (2011).**

# Impact of Single-Processor Performance Plateau

Accentuated by emergence of **massive data sets,** scientists have an increasing appetite and need for speed and performance.

Important new science questions in **physics, materials, biology, health and medicine, and climate change** require increased processing power.

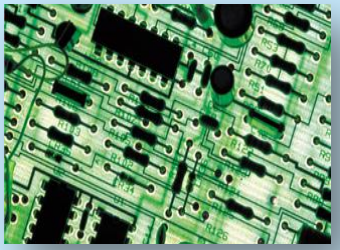
**Support of national defense and intelligence community** will need increasingly more processing power.

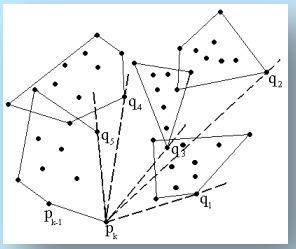
Applications include training simulations, autonomous robotic vehicles, airport security, surveillance, video analytics, infrastructure defense against cyber attacks, and data analysis for intelligence.

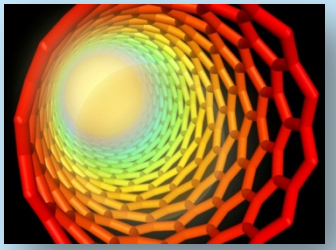
Both **consumer and enterprise needs** are increasing.

Applications include search and data mining, real-time decision-making, web services, digital content creation, speech recognition, and simulation and modeling for product design.

# Research to Expand the Limits of Computation







## Happening now

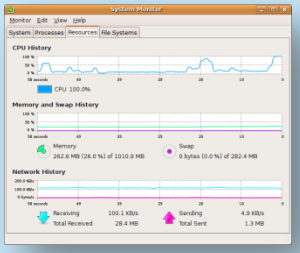
- Architectural innovations with multi-core and many-core
- Domain-specific integrated circuits
- Energy-efficient computing and new processor architectures

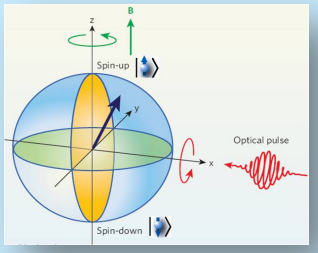
## Mid-term solutions

- Need to fully exploit broadly available concurrency and parallelism
- Algorithmic innovations exploiting parallelism
- Software systems leading to improved performance

## Long-term solutions

- New materials (e.g., carbon nano-tubes, graphene based devices)
- Non-charge transfer devices; (e.g., electron spin)
- Bio, nano, and quantum devices

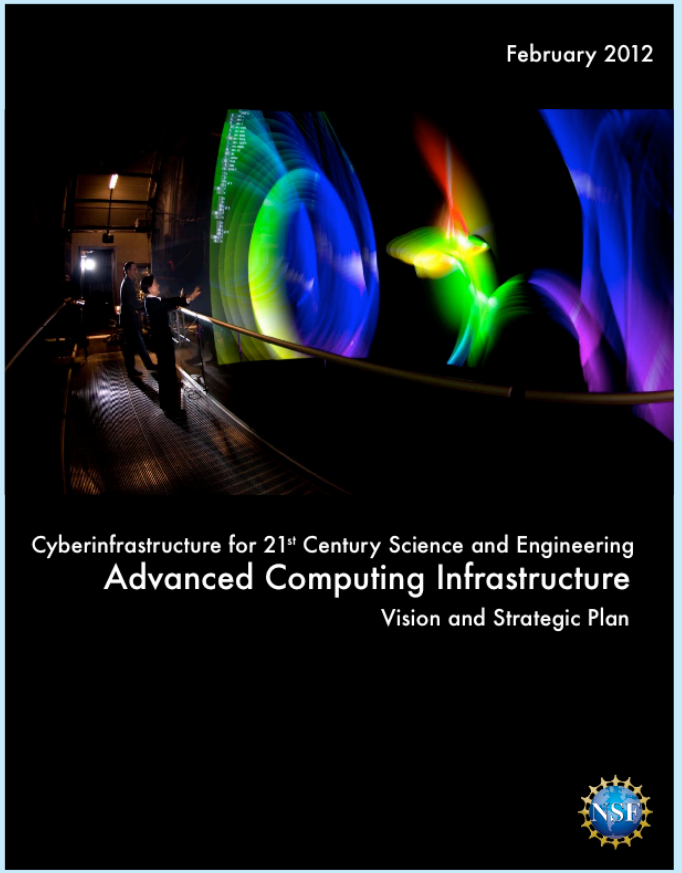




# Exploiting Parallelism and Scalability (XPS)

## New program announced October 2012

- **Computational models and programming languages** to enable new ways of “thinking parallel” and expression of parallelism at every scale.
- **Algorithms and algorithmic paradigms** that allow reasoning about parallel performance and scalability.
- **Software systems** capable of handling both small and extreme-scale data systems and aware of communication and energy use.
- **Synthesis tools** that generate efficient parallel codes from high-level descriptions.
- **Scalable and energy-efficient architectures** ranging from sensors to clouds while addressing programmability, reliability, and security.
- **A new cross-layer approach** integrating both software and hardware through new programming languages, models, algorithms, compilers, runtime systems and architectures.

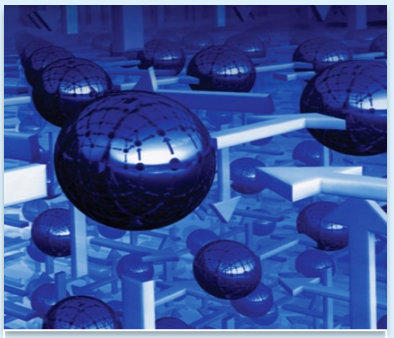



www.nsf.gov/pubs/2012/nsf12051/nsf12051.pdf

# Emerging Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision



Expanding the Limits of Computation

Secure Cyberspace

Universal Connectivity

Augmenting Human Capabilities

# Cyber Security Challenge

- **Attacks and defenses co-evolve**: a system that was secure yesterday might no longer be secure tomorrow.
- The technology base of our systems is frequently updated to improve functionality, availability, and/or performance. **New systems introduce new vulnerabilities** that need new defenses.
- The **environments** in which our computing systems are deployed and the functionality they provide are **dynamic**, e.g. cloud computing, mobile platforms.
- As **automation pervades new platforms**, vulnerabilities will be found in critical infrastructure, automotive systems, medical devices.
- The **sophistication** of attackers is increasing as well as their sheer **number** and the **specificity** of their targets.
- Cyber security is a **multi-dimensional** problem requiring expertise from CS, mathematics, economics, behavioral and social sciences.


Image Credit: *ThinkStock*

# Secure and Trustworthy Cyberspace (SaTC)

***Securing our Nation's cyberspace***

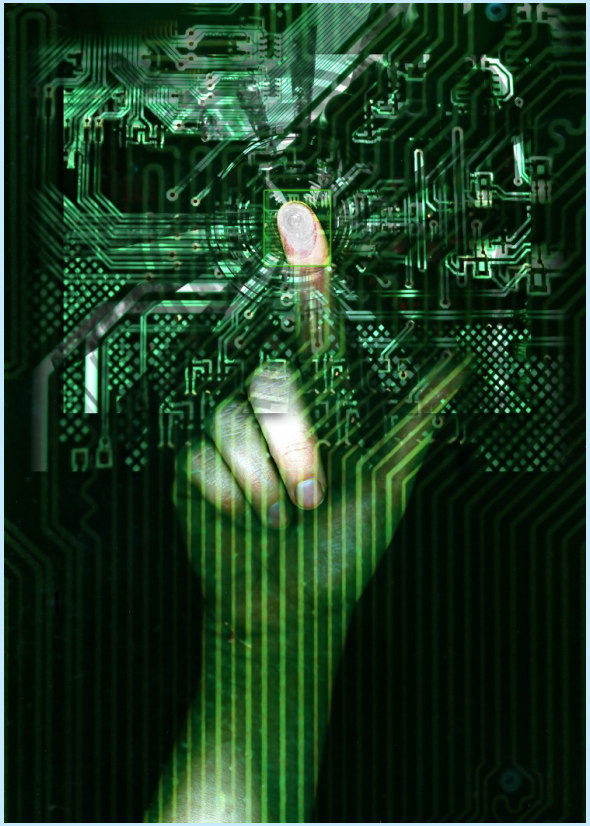


Image Credit: *ThinkStock*

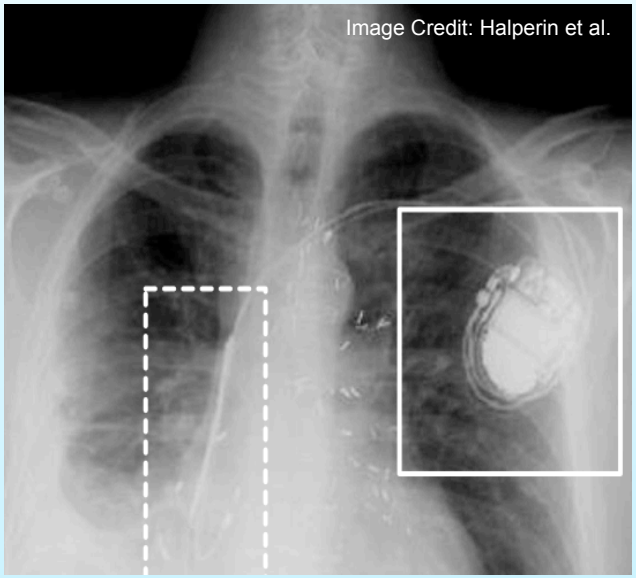
- Aims to support fundamental scientific advances and technologies to protect cyber-systems from malicious behavior, while preserving privacy and promoting usability.
- Program addresses three perspectives:
  - Trustworthy Computing Systems
  - Social, Behavioral and Economic Sciences
  - Transition to Practice
- *Frontiers* support center-scale activities

Cross-Directorate Effort: CISE, ENG, EHR, MPS, OCI, and SBE

# Cyber-physical Security

Image Credit: Karl Koshner

**Security Risks in Automobiles:** Demonstrating the ability to remotely take over automotive control systems has led to a collaboration with the automotive industry to develop new methods for assuring security and safety of automotive electronics. (Stefan Savage, UC San Diego and Tadayoshi Kohno, U Washington)

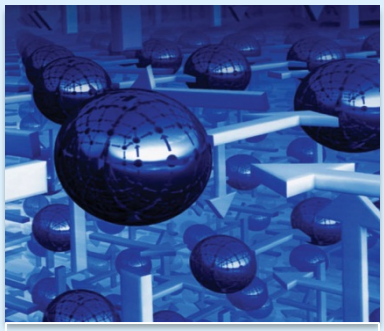



**Implantable Medical Device Security:** Demonstrating the ability to gain wireless access to a combination heart defibrillator and pacemaker to turn it off and deliver jolts of electricity have resulted in a collaboration with physicians to secure these devices against extraneous signals and attacks. (Kevin Fu, UMass – Amherst)

# Research Frontiers

Data Explosion

Smart Systems: Sensing, Analysis and Decision



Expanding the Limits of Computation

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# Explosive Growth in Volume & Traffic Diversity

**VoIP** → 663M registered Skype users in September 2011. Represents 20% of long distance minutes world-wide. If Skype were a carrier, it would be the 3rd largest in the world (behind China Mobile and Vodaphone). Largest provider of cross-border communication.

**Video** → Recent estimates as high as 60% of internet traffic is video and music sharing; 35 hours of new videos are uploaded every minute in 2011; 2 billion views per day.

**Twitter** → Expected to reach 500M registered users in 2012.

**Broadband** → 20% of global internet users have residential broadband; 68% in U.S. subscribe to broadband.

***1988***

*Remarkable Pace of Innovation*

***Today***

# What Happens in an **Internet Minute?**


## And **Future Growth** is **Staggering**



Credit: Intel Corporation

# Cellular Networks, Mobile Devices and Pervasive Computing

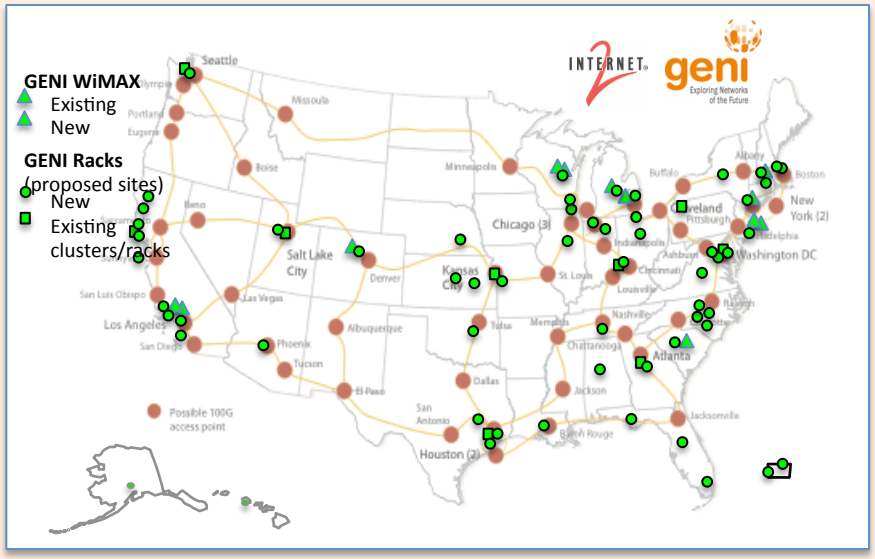
- 5.3 billion mobile phone subscribers; 85% of new handsets will be able to access the mobile web; 1 in 5 has access to fast service, 3G or better; IM, MMS, SMS expected to exceed 10 trillion message by 2013.
  - Only digital system accessible to the majority of the planet.
- Growing ecosystem of tools and applications:
  - Banking, commerce, healthcare, social networking: 600K distinct active apps just in App Store.
  - Mobile browsers can now display much of the content available to their desktop counterparts.
- Mobile payment systems are now common in the developing world.
- Sensitive and private data stored & entered on devices.

Image Credit: Nicolle Rager Fuller, NSF

**Research Themes:**

| Infrastructure scalability | Spectrum management | Security and privacy | Energy consumption | Leveraging and advancing new networking technologies |
|---|---|---|---|---|

# Mid-scale Research Infrastructure




***Advancing networking, distributed systems, cloud computing and cybersecurity research through experimentation at scale***

**Global Environment for Networking Innovations (GENI)**

- A virtual laboratory for exploring future internets at-scale, now taking shape in prototype form across the U.S.
- Key GENI concepts:
  - Slices & deep programmability
  - Federation and enabling “at scale” experiments

**US Ignite**

- Launched June 14, 2012 at the WH
- NSF leadership
  - Leveraging GENI investments
  - Stitching together testbeds and network resources across the country
  - Jumpstarting gigabit public sector application development
- Public Private Partnership
  - Bringing industry and foundations into he mix

**NSF Cloud**

- Virtualization beyond the network to resources located in the “cloud”
- Develop competing prototypes
- Allow for experimentation not possible elsewhere

# Research Frontiers

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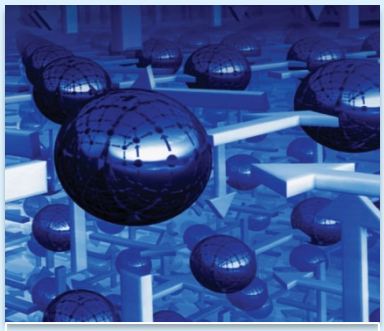

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# Networked Society

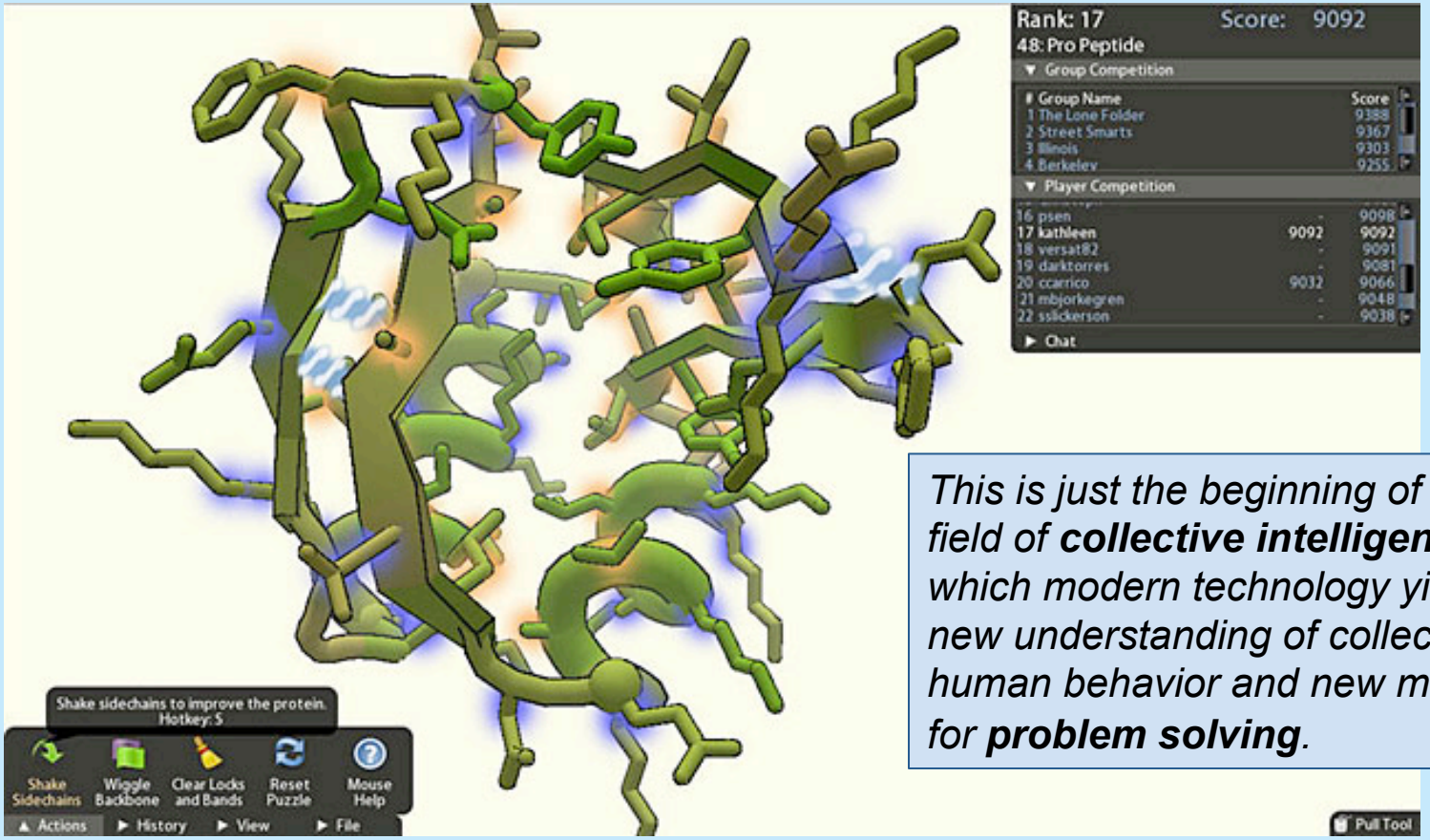
***Computing technologies and human societies co-evolve, transforming each other in the process***

- We are increasingly becoming a networked society.
- Access to technology and information is enhancing our cognitive and physical capabilities.
- This trend will be accelerated by advances in:

  - social informatics
  - assistive technologies
  - augmented reality
  - robotics
  - crowd sourcing
  - learning technologies
  - natural language understanding
  - vision and perception
  - artificial intelligence
  - machine learning
  - information retrieval

# Social Networks Solving Complex Problems

***Networks of human minds are taking citizen science to a new level***



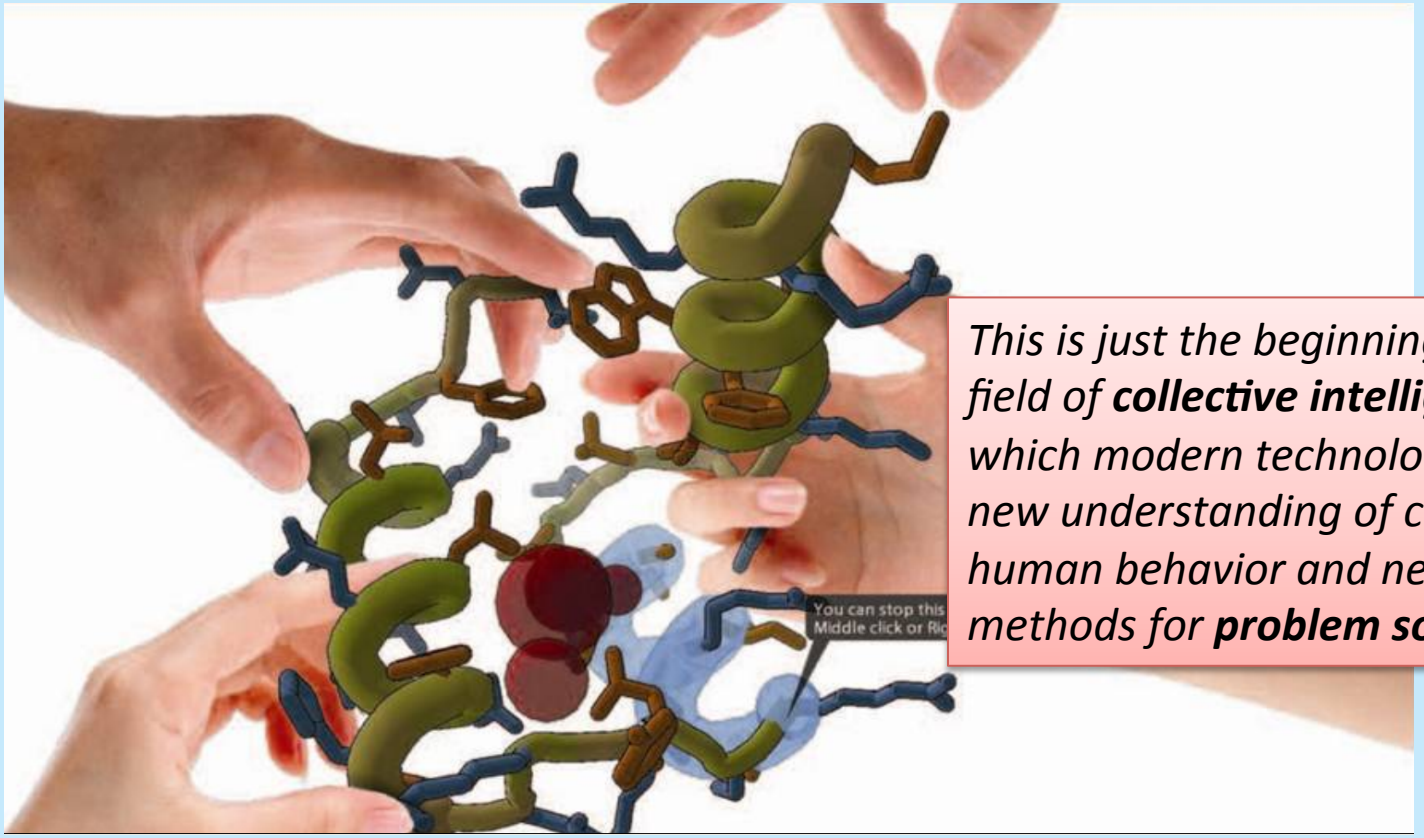

*This is just the beginning of a new field of **collective intelligence** in which modern technology yields new understanding of collective human behavior and new methods for **problem solving**.*

Image credit: Seth Cooper, David Baker, Zoran Popović, Firas Khatib, Adrien Treuille, Jeff Flatten, Kefan Xu, Dun-Yu Hsiao, Riley Adams, Center for Game Science, University of Washington

In 2011, players of Foldit helped to decipher the crystal structure of the Mason-Pfizer monkey virus (M-PMV) retroviral protease, an AIDS-causing monkey virus. Players produced an **accurate 3D model** of the enzyme **in just ten days**. The problem of how to configure the structure of the enzyme had **stumped scientists for 15 years**.

# Social Networks Solving Complex Problems

***Networks of human minds are taking citizen science to a new level***

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Foldit image: Univ. Washington Center For Game Science; artwork by W. Fernandes, Nature, Aug 2010

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# Augmenting Human Capabilities

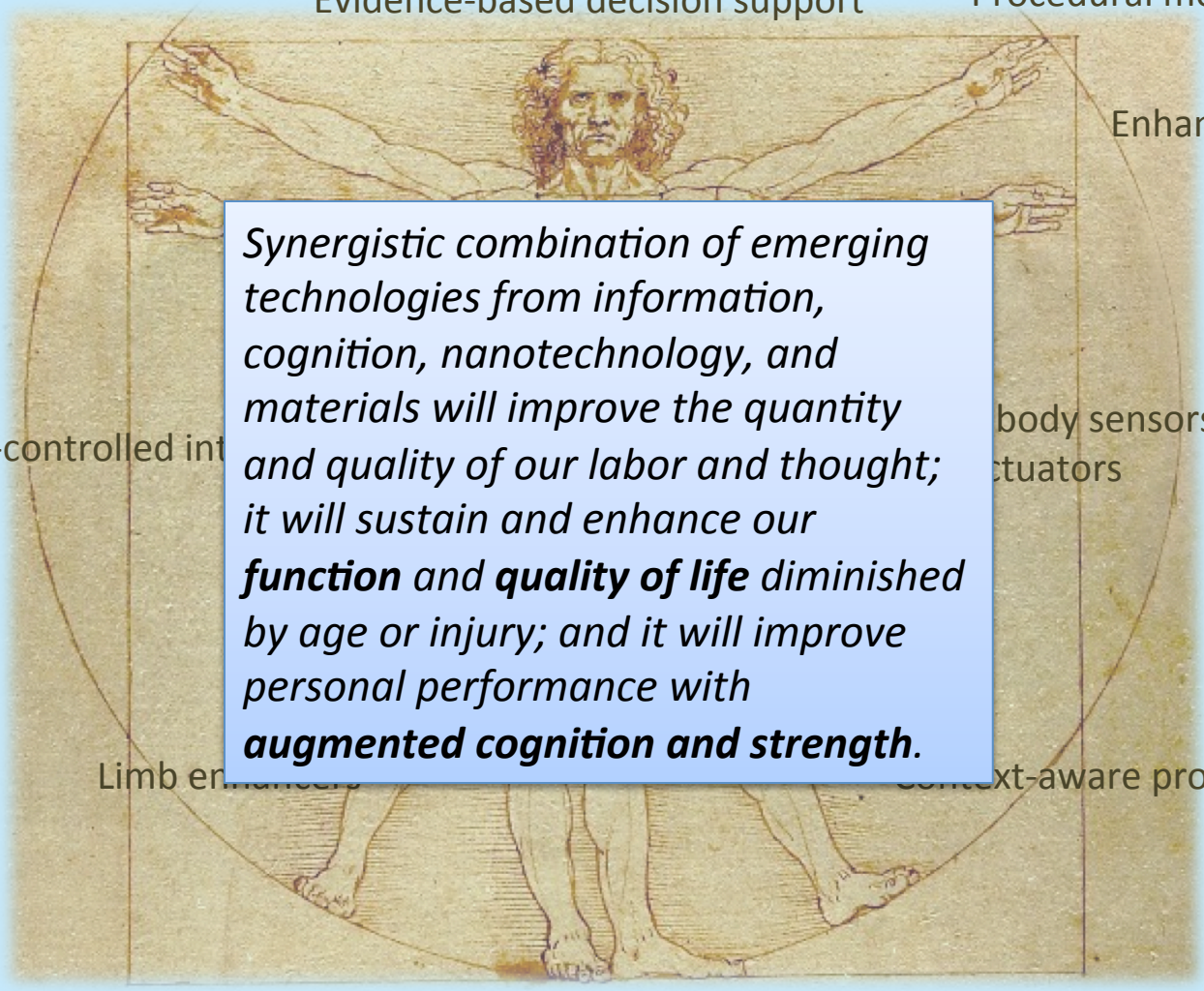
***Converging technologies for enhancing performance and quality of life***

MEMEX

Evidence-based decision support

Procedural memory coach

Enhanced perception



*Synergistic combination of emerging technologies from information, cognition, nanotechnology, and materials will improve the quantity and quality of our labor and thought; it will sustain and enhance our* ***function*** *and* ***quality of life*** *diminished by age or injury; and it will improve personal performance with* ***augmented cognition and strength****.*

Brain-controlled int

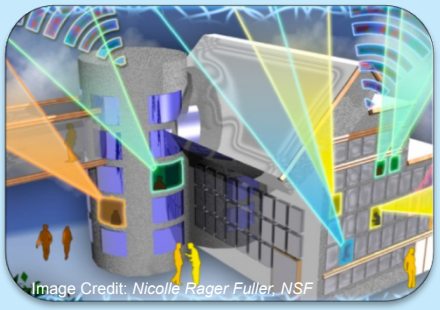
body sensors

ctuators

Limb en

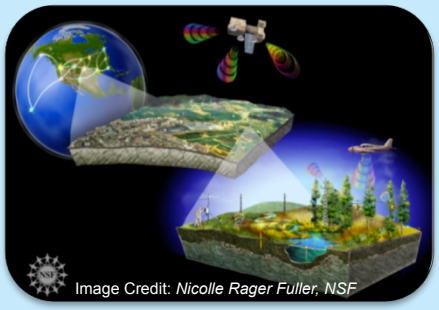
xt-aware prosthetics

# CISE and National Priorities




**Broadband & Universal Connectivity**


**Emergency Response & Disaster Resiliency**




**Environment & Sustainability**

**Health & Wellbeing**


**Manufacturing, Robotics, & Smart Systems**


**Secure Cyberspace**


**Transportation & Energy**

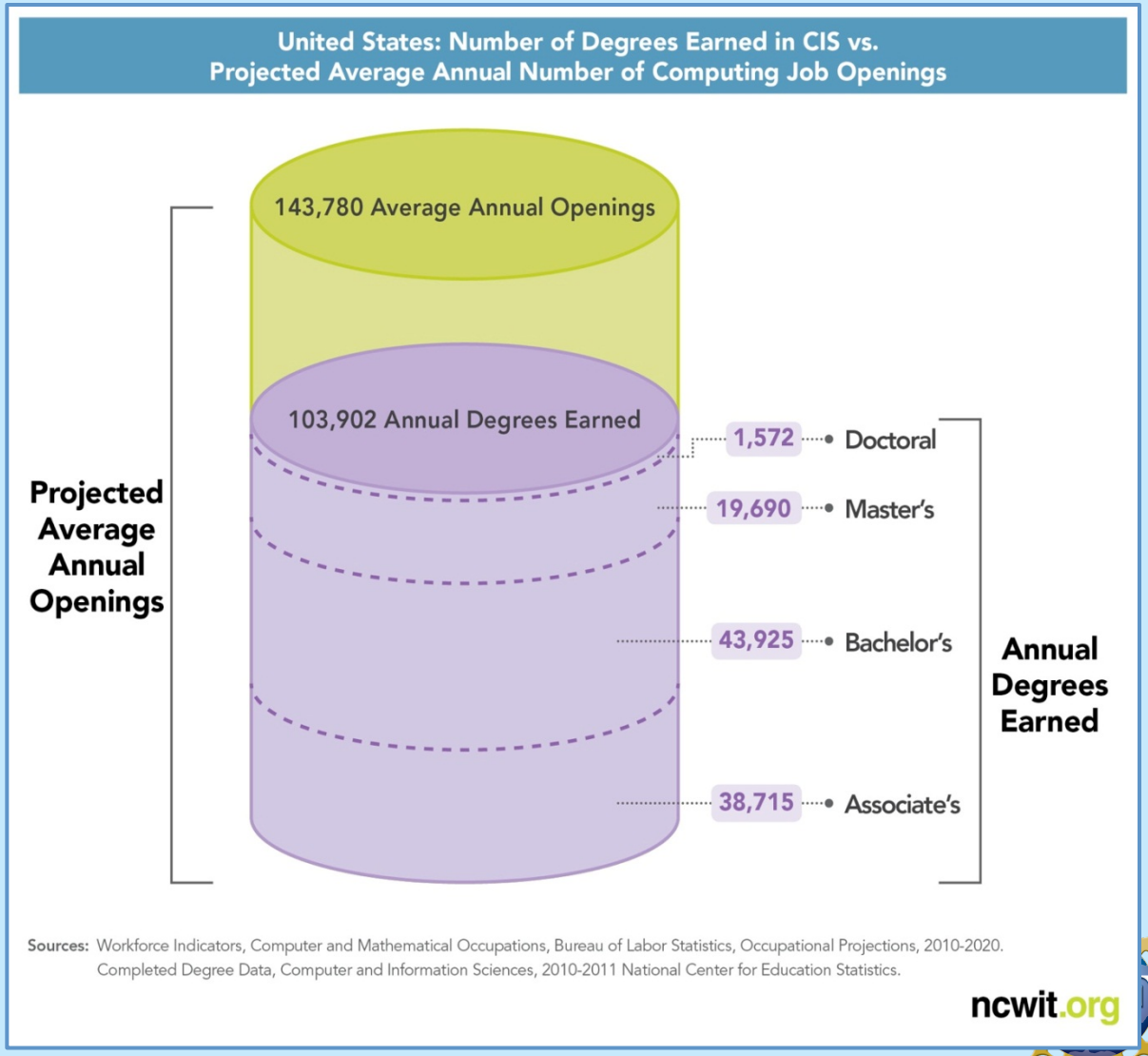

**Education and Workforce Development**

# The computing community faces three significant and interrelated challenges in workforce development

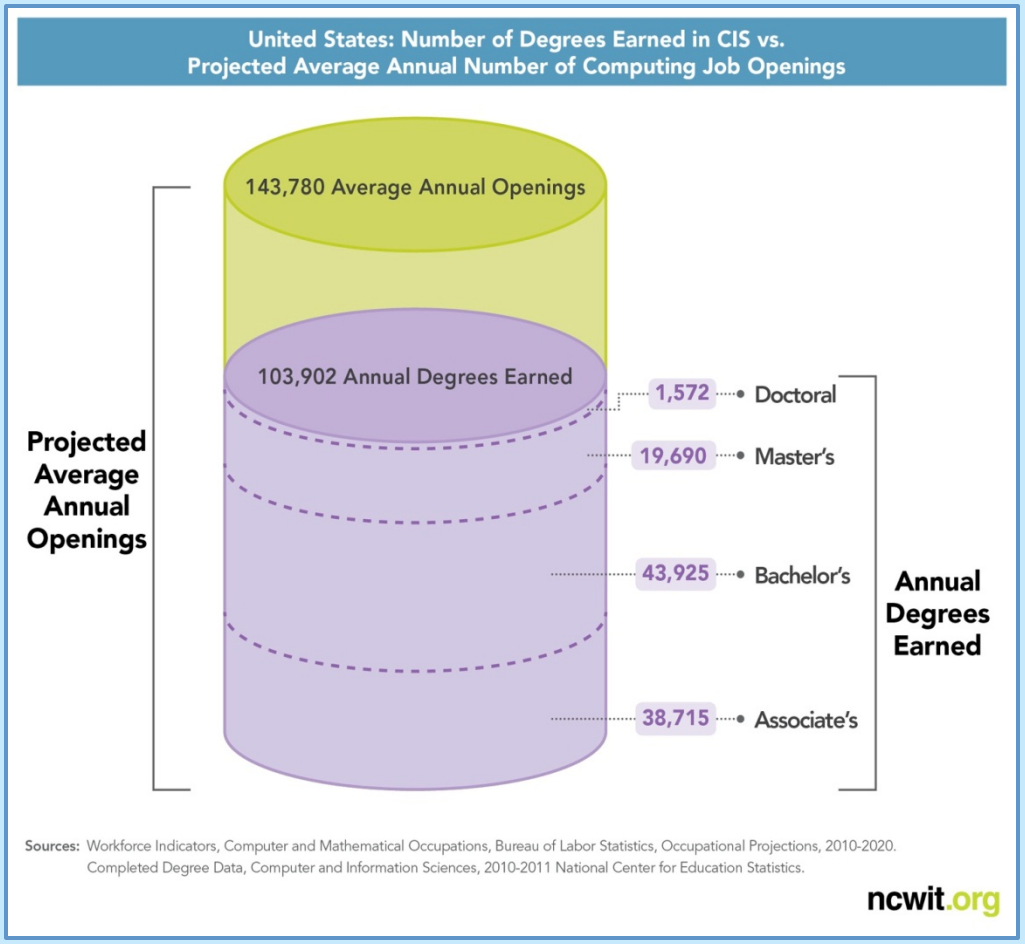
**Underproduction of degrees**

**Under-representation**

**Lack of a presence in K-12**



# Underproduction

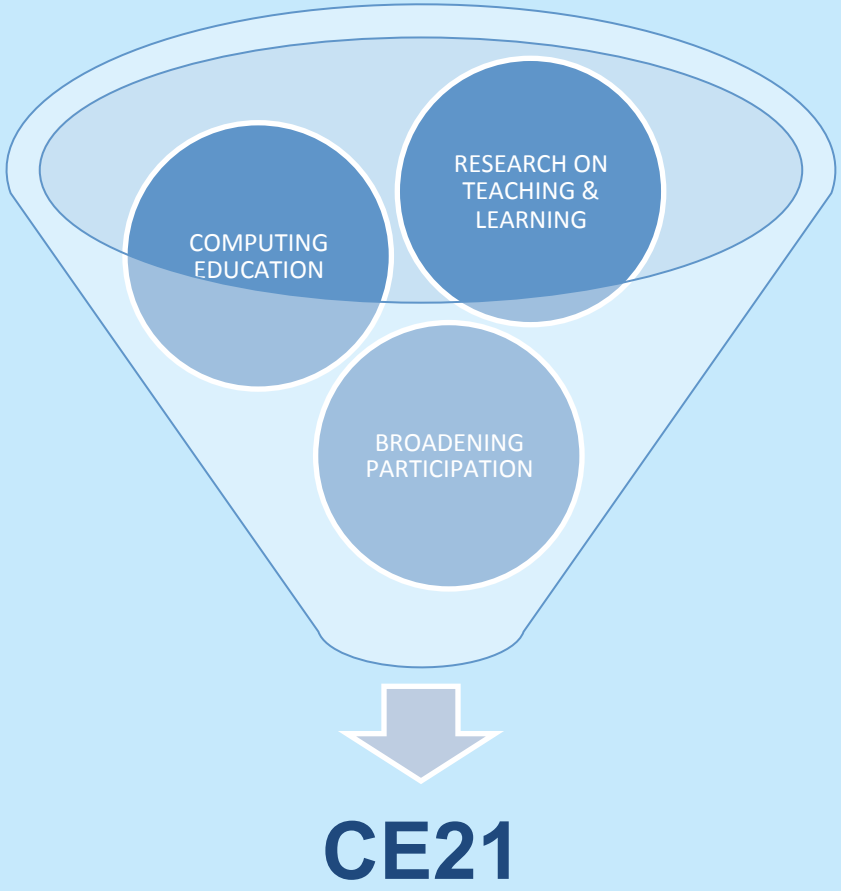



# Underrepresentation

- Women, African Americans, Hispanics, Native Americans and indigenous people, and persons with disabilities—together representing 70% of US population—participate in very low numbers in computing.
- While there are disciplines with lower numbers, computing is the only field where the gender gap has grown significantly over the last 20 years (mostly at the undergraduate level).

# Computing Education for the 21st Century (CE21)

***Enhancing computational competencies***



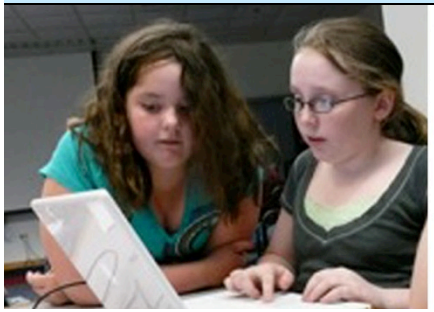

- Increase number and diversity of K-14 students and teachers who develop and practice computational competencies
- Increase number of postsecondary students who have background necessary to pursue degrees in computing and computationally-intensive fields
- Build a research base for CS 10K Project
- Cross-Directorate Program: CISE, EHR, OCI

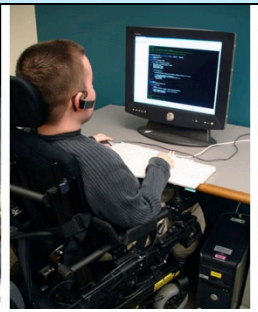
# CS10K

***Transforming high school computing***

**Get engaging, rigorous curricula into computing courses in 10,000 high schools, taught by 10,000 well-prepared teachers by 2016.**

- New preAP course, *Exploring Computer Science (ECS)*
- New (proposed) AP Course, *CS Principles*
- Develops scalable models, curricula and materials for professional development for teachers
- Fosters the growth of national community and partnerships needed to scale to 10,000 teachers & schools





# Cyberlearning

***Improving learning by integrating emerging technologies with knowledge from research about how people learn***

Computer science is both the **enabling discipline** for the development of technologies that enhance learning and a discipline with an **immediate and critical need** for cyberlearning technologies as it aims to scale K-16 educational transformations at the national scale

**Goals:**

- Understand how people learn in technology rich environments
- Design and study ways in which innovative technologies and tools can promote learning and support assessment
- Prototype new technologies and integrate them into learning environments

# Advancing the Research Frontiers Requires the Right Science at the Right Scale

# Programmatic Innovations

- ***INSPIRE****: Integrated NSF Support Promoting Interdisciplinary Research and Education*
- ***Innovation Corps (I-Corps)****: Public-private partnership to catalyze a national innovation ecosystem*
- ***SAVI:*** *Science Across Virtual Institutes*
- ***CISE Center-Scale Research Efforts****:*
  - *Expedition-in-Computing*
  - *Frontiers in Cybersecurity*
  - *Frontiers in Cyber-Physical Systems*

# Expeditions-in-Computing

***Exploring scientific frontiers that promise transformative innovations in computing***

- $10M total per project
  - $2M/year per award for 5 years
- 14 awards to date (4 awards In FY 2012)

Credit: Jason Dorfman, CSAIL/MIT

### Beyond Moore's Law

- *Variability-aware Software for Efficient Computing with Nanoscale Devices*, UCSD, UCLA, UIUC, Stanford, Michigan, 2010
- *Customizable Domain-Specific Computing*, UCLA, UCSB, Rice, Ohio State, 2009
- *The Molecular Programming Project*, CalTech, U Washington, 2008

### Sustainability & Environment

- *Understanding Climate Change: A Data Driven Approach* – Minnesota, Northwestern, NC State, NC A&T State, 2010
- *Computational Sustainability: Computational Methods for a Sustainable Environment, Economy, and Society* – Cornell, Oregon State, Bowdoin, 2008

### Wireless & Internet

- *Open Programmable Mobile Internet 2020,* Stanford, 2008

### Healthcare & Wellbeing

- *Computational Behavioral Science: Modeling, Analysis, and Visualization of Social and Communicative Behavior,* Georgia Tech, MIT, Boston U, UIUC, USC, *Carnegie Mellon, 2010*
- *Socially Assistive Robots, Yale, USC, MIT, Stanford, Willow Garage, 2012*

### Robotics

- *RoboBees: A Convergence of Body, Brain and Colony – Harvard, Northeastern, 2009*
- *An Expedition in Computing for Compiling Printable Programmable Machines, MIT, U Penn, Harvard, 2012*

Image Credit: Harvard University

### Limits of Computation

- *Understanding, Coping with, and Benefiting from Intractability* – Princeton, Rutgers, NYU, Institute for Advanced Study, 2008

### Formal Modeling and Verification

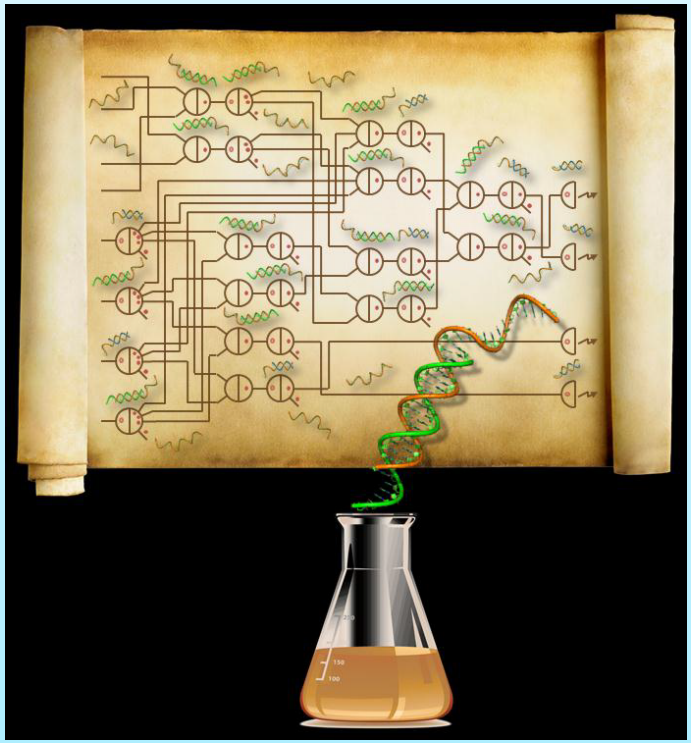
- *Next-Generation Model Checking and Abstract Interpretation with a Focus on Embedded Control and Systems Biology, Carnegie Mellon, Stony Brook, NYU, UMD, Pitt, Lehman College, JPL, 2009*
- *Expeditions in Computer Augmented Program Engineering, U Penn, UC Berkeley, UMD, Rice, Cornell, U of Michigan, U of Illinois-UC, UCLA, MIT, 2012*

### Big Data

- *Algorithms, Machines, and People, UC Berkeley, UC San Francisco, 2012*
- *Understanding Climate Change: A Data Driven Approach* – Minnesota, Northwestern, NC State, NC A&T State, 2010

# Expeditions-in-Computing

**Programming with DNA:** Employing logic circuits using DNA and RNA has the potential to change the way we analyze, understand, and manipulate molecular systems. (Erik Winfree, Caltech, et al.)



**RoboBees:** Microrobots with real-time sensing and communication capabilities with the potential to impact assisted agriculture, search and rescue, and environmental monitoring. (Robert Wood, Harvard, et al.)

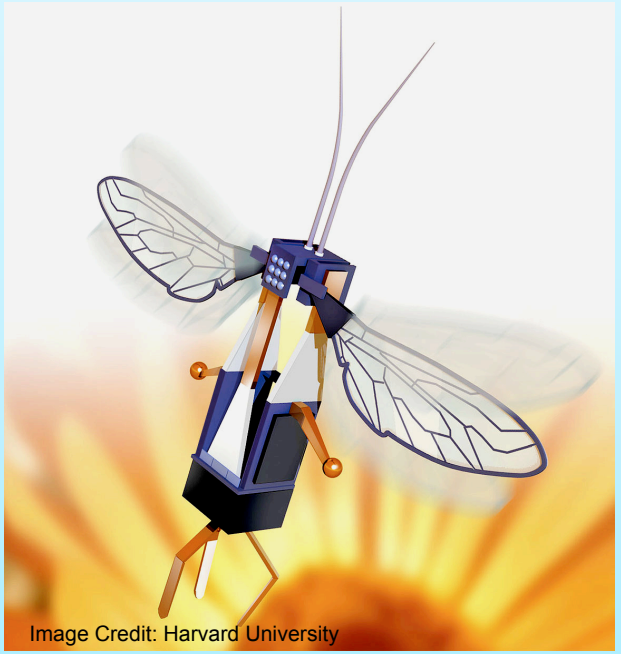
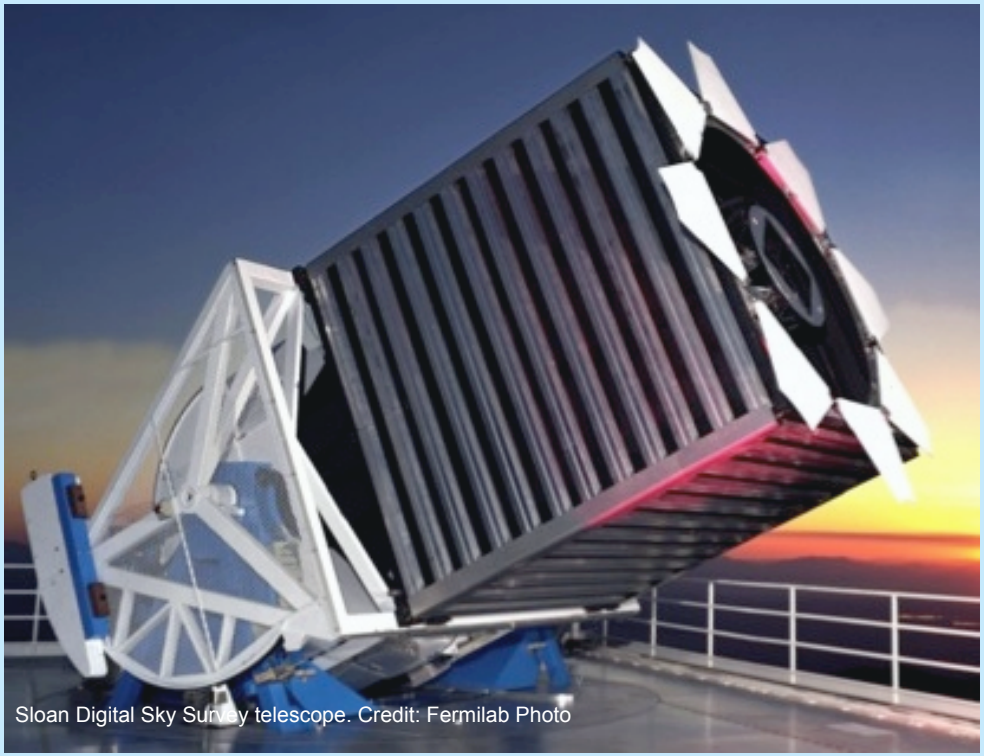


Image Credit: Harvard University

# Looking Forward



Sloan Digital Sky Survey telescope. Credit: Fermilab Photo

# Moving ahead

**Nurture and Support a Culture of Engagement and Service**

- Help shape the future directions of the field, priorities for the nation, and formulate a research and education agenda to address societal challenges.

**Embrace a Collaborative Culture Enabled by Foundational Research**

- Advances in IT and CI are pushed by long-term investment in foundational research and cross- and inter-disciplinary research and pulled by expanding complexity, scope, and scale of global priorities.

**Educate and Empower the Next Generation**

- Lead a cyber- and technology-enabled transformation in education and learning to develop the next generation IT workforce and contribute to universal, transparent, and affordable participation in a knowledge-based society.

# The Growing Imperative of Research and Education in Computing

- Our investments in **research and education** have returned exceptional dividends to our nation.
- A thriving basic research community is the foundation for long-term **discovery** and **innovation**, **economic prosperity**, and **national security**.
- As a field of inquiry, computer, communication and information science and engineering has a **rich intellectual agenda** – highly creative, highly interactive, with enormous possibilities for changing the world!
- To keep those benefits flowing, we need to constantly **replenish** the wellspring of **new ideas** and train **new talent**.


*Thanks!*

fjahania@nsf.gov